PRACTICAL SERIES

PRACTICAL SURVEYOR'S GUIDE

THE

PRACTICAL SURVEYOR'S GUIDE,

CONTAINING

THE NECESSARY INFORMATION TO MAKE ANY PERSON
OF COMMON CAPACITY,

A FINISHED LAND SURVEYOR,

WITHOUT THE AID OF A TEACHER.

BY

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PHILADELPHIA:
HENRY CAREY BAIRD,
(SUCCESSOR TO E. L. CAREY.)

LONDON:
LOW, SON & CO.
1854.

STEREOTYPED BY SLOTE & MOONEY,
Philadelphia.

ADVERTISEMENT.

The intention of the Author of the following synopsis is to furnish a cheap, small book containing the best practical information hitherto published and scattered through many eminent authors, nearly all of which he has carefully studied, and having had more than thirty years' experience as a Surveyor, &c., has often had occasion to carry large works in order to have at hand the things necessary in the immediate field practice of surveying, levelling, profiling, calculating excavations, embankments, &c. To render the book as cheap as possible, the tables shall be only those that are really wanted, but by which all things in common practice can be readily done, viz: Latitude and departure, for four pole chains. A table of natural sines, cosines, and tangents, which are most useful for finding the radius of curves, degree of curvature, &c., on railroad and other curves, their application in finding grades, cuttings, fillings, &c., will, it is hoped, prove useful.

Geometrical demonstrations are avoided, except in a few cases, the design of the writer being to furnish a short treatise, to direct at once to what is required.

The work will be comprised in four divisons:

1st. The arithmetical calculation of plane figures.

2nd. The calculation of surveys taken with the compass and chain by latitude and departure, with various methods of proof.

3d. The method of plotting, enlarging and diminishing maps, with remarks on copying and embellishing.

4th. Levelling, profiling and calculating cuttings and embankments, the use and application of the tables, together with many other useful things applicable in practice.

PREFACE.

The following compilation is made in consequence of the undersigned not having met with any work on Surveying sufficiently concise, and instructive in the several details, necessary to qualify properly the practical surveyor. Many of the works already published contain subjects not necessary in such treatises; such as Geometry, Plane Trigonometry, &c., which subjects, it is taken for granted, all who intend to become proficients have studied prior to reading Surveying. They are also found not to contain instruction that in recent improvements the surveyor requires to know. Many of these things the compiler of this short treatise, will endeavour to supply; also, many other necessary things, which, in his long experience, he has found indispensable to the correct practitioner. He has collected the most necessary instruction in leveling and profiling, with a new and speedy plan of setting grades on rail and plank roads. The method of inflecting curves, not hitherto sufficiently explained. The description and design of a new instrument whereby distances are found at once without any calculation. A new method of surveying any tract of land by measuring one line through it, with a geometrical demonstration of the same. A geometrical method of correcting surveys taken with the Com-

pass, to fit them for calculation, with a table of corrections for certain distances, but applicable to all. A short method of finding the angles from the courses, and *vice versâ*. The method of surveying with the Compass through any mine or iron works, and to correct the deflections of the needle by attraction. Description of an instrument by the help of which any gentleman may measure a map by inspection, without calculation. A new and short method of calculation, wherein fewer figures are used than in the common method; also, the Pennsylvania method. Tables of difference of Latitude and Departure, made expressly for two pole chains, but which can also be used with four poles. The method of correcting the diurnal variation of the needle, most useful in tracing the boundaries of surveys, a complete description of which is given with the reason for using 57-3° and how it is found. Various methods of plotting and embellishing maps. The most correct method of laying off lots with a pole, plummets, &c. Description of a new Compass which the compiler has contrived for that purpose, and which is made by REID & SONS, Smithfield street, Pittsburgh.

The compiler does not deny that he has borrowed from many authors those things he has found best adapted to the completion of a work adequate to make a finished American Surveyor, of which an unprejudiced and enlightened public are the best judges.

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PRACTICAL SURVEYOR'S GUIDE.

PROBLEM FIRST.

To reduce two pole chains and links to four pole ones.

If the number of chains be even, the half of them will be four pole ones, to which annex the given links. Thus:

1. In 16 chains, 37 links of two pole chains how many four pole ones:

$$\begin{array}{r} 2)16.37 \\ \hline \textit{Ans.}\quad 8.37 \end{array}$$

But if the number of chains be odd, take half of them and add 50 to the links. Thus:

$$\begin{array}{r} 2)131.40 \\ \hline \textit{Ans.}\quad 65.90 \end{array}$$

PROBLEM SECOND.

To reduce four pole chains and links to two pole ones. Double the chains and annex the links if

they be less than 50, but if they exceed 50, add one to double the chains and take 50 from the links. Thus: $\overset{c.}{16}.\overset{l.}{25}$ of four poles, how many two pole chains.

$$\begin{array}{rl} & 16.25 \\ & 2 \\ \hline \textit{Ans.} & 32.25 \end{array}$$

2d. In $\overset{c.}{19}.\overset{l.}{87}$ four pole chains how many two pole ones.

$$\begin{array}{rr} & 19.87 \\ & 2.50 \\ \hline \textit{Ans.} & 39.37 \end{array}$$

To reduce two pole chains and links to perches and decimal of a perch, multiply the chains by two and the links by four, thus: In $\overset{c.}{16}.\overset{l.}{37}$ how many perches.

$$\begin{array}{rr} & 16.37 \\ & 2.\ \ 4 \\ \hline \textit{Ans.} & 33.48 \end{array}$$

ARTICLE FIRST—OF AREAS.

A square is a plane figure having four equal sides and four right angles. To find the content,

multiply the side into itself and the product is the content.

EXAMPLE.

Required the area of the square A B C D, one of whose sides is 25 chains 95 links.

```
    25.95
    25.95
    -----
    12975
   23355
  12975
  5190
 ---------
A. 67.34025
         4
 ---------
R. 1.36100
        40
 ---------
P. 14,44000
```

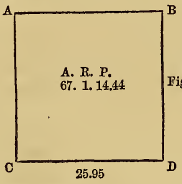


Fig. 1.

A parallelogram is a four sided figure whose opposite sides and angles are equal. To find the area multiply one of the sides by the perpendicular demitted from one of its opposite angles.

EXAMPLE.

Required the area of the parallelogram A B

C D, the length of which is 15 chains, and height $\overset{c.}{12}\ \overset{l.}{64}$.

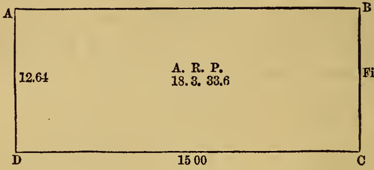


Fig. 2

12.64
15
———
6320
1264
———
Acres, 18,960
4
———
Roods, 3.840
40
———
Perches, 33,600

The content of an oblong piece of ground and one side are frequently given to find the other. Divide the area in perches by the given side, gives the side required which is easily reduced into chains and links.

If a lot contains 507 perches and is $\overset{c.}{14}.\overset{l.}{25}$ long, what is its width.

```
29)507            2)  4)
   29              17.4827
   --             ---------       C.  L.
   217.0000       8.25+12.06=8  37.06
   203
   ----
    140
    116
    ----
     240
     232
     ----
       80
       58
       ---
        220
        203
```

To draw maps of these figures is too obvious to require any explanation.

5th. When the sides of the above figures are given in feet and inches, reduce the inches to decimal of a foot. Then multiply the length by the breadth and divide the product by 43560, the number of feet in an acre, the quotient will be the acres and decimal of an acre, which may be reduced to roods and perches by multiplying by 4 for the roods and 40 for the perches, pointing off the proper number of decimal places each time, thus:

A lot of land is 600 feet 4 inches long and 240

feet 3 inches wide, how many acres does it contain.

600.333.×240.25=144230.00325

	Acres.	A.	R.	P.
This divided by 43560. gives	3.31106 or	3	1	09.76
	4			
	1.24424			
	40			
	9.76960 *Ans.*			

6th. A trapezium is a four sided figure the opposite sides of which are neither equal nor parallel. To find the content, measure a diagonal and two perpendiculars to the opposite corners, multiply the diagonal by half the sum of the perpendiculars, and the product will be the area.

EXAMPLE.

Let A B C D be any trapezium, having A C 80 perches, and the perpendiculars as in the figure.

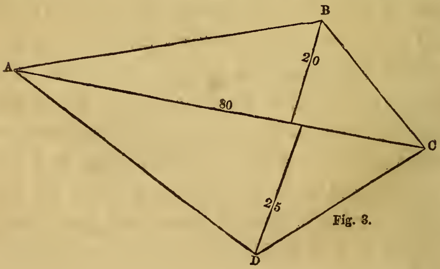


Fig. 3.

```
                25
                20
                ——
              2)45
               ———
              22.5
                 80
             ———— A. R. P.
    160)1800,0(11.1.00   Ans.
         160
        ————
         200
         160
        ————   R.
      40)40(1
         40
        ————
```

7th. A triangle is a figure having three sides and three angles, any side may be called the base, having the base and perpendicular given. Multiply the base by half the perpendicular, or the base by the whole of the perpendicular, and take half the sum.

EXAMPLE.

Let A B C be any triangle whose base is 100 two pole ch's and 15 links, and perpendicular 40

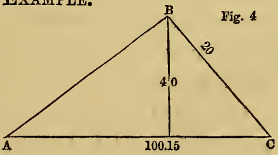


Fig. 4

chains and 20 links, required the content in acres.

		100 15	
		2 4	
40 20		200.6	perches and decimal.
2 4		40.4	half the perpendicular.
2)80 8		8024	
		8024	
40 4		A. R. P.	
		160)8104.24(50 2 24.24	*Ans.*
		800	
		40)104	
		80	
		24	

8th. Having the three sides given to find the area rule, add the three sides together and take half the sum, from which subtract each side severally, multiply the half sum and three remainders continually into each other, and the square root of the product will be the area.

The most satisfactory proof of the above rule is the following:

Let A B C be any triangle, B C its base, A B the greatest side, and A C the least, and let P be half

the perimeter. In A B take A D=A C, join D C and draw A E perpendicular to D C and E G parallel to B C cutting A B in G, with the centre G and radius G E describe a circle cutting A B in L and A B and E G produced in K and H. Join H B and produce A E, H B till they meet in M.

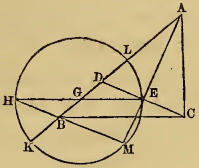


Fig. 5.

Since A D=A C and the angles at E are right, the squares of A E, E D are equal 2 A E,+2 E C and ∴ E D=E C or D C=2 D E. Hence by similar triangles D G E, D B C, B C=2 G E=E H, and B C is also parallel to E H ∴ H B M is parallel to C E D and (Euc. 1st 29th) the angle B M E=D E A, viz: a right angle, and H E being a diameter, M is a point in the circle. But from similar triangles D G E, D B C, D B=2 D G, to each of these equals add A D+A C=2 A D, and B A+A C=2 A G, to each of which equals add B C=2 G E=2 G K ∴ A B+A C+B C=2 A K or A K is =P, half the perimeter. Now the area of the triangle A B C=area A D C+area B D C=A E×D E+

2*

M E×D E (B M being parallel to D C)=A M×D E. But by similar triangles A D E, A M B : A E : E D :: A M to M B, and by equi-multiples the first multiplied by third : the second multiplied by the third :: the second × by the third : the second × by the fourth. Hence, A E×A M : E D×A M :: E D×A M : E D×M B, i. e. the area of the triangle is a mean proportional between A E×A M, and E D×M B. Now E D×M B,= P—A B×P—A C, and A E×A M=A L×A K= P×P—B C. Hence the area of the triangle is: $\sqrt{P \times P - AB \times P - AC \times P - BC}$, which is the rule.

EXAMPLE.

9th. Suppose the sides to be measured by a four pole chain and be

	C. L.
A B	10. 64
A C	12. 28
B C	9. 00
Sum	31. 92
½ sum	15. 96
	5. 32 first remainder.
	3. 68 second do.
	6. 96 third do.

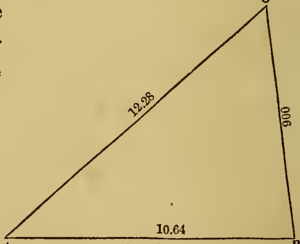


Fig. 6.

$$15.96 \times 5.32 \times 3.68 \times 6.96 = 2174.71013216(46.6337$$

16

86)574
516

926)5871
5556

9323)31501
27969

93263)353232
279789

932667)7344316
6528669

And since 10 square 4 pole ch's make one acre, this becomes

ACRES.
4.66337
4
2.65348
40
26.13920

The content is 4 A. 2 R. 26 P.

If the sides are in perches and decimal, divide the square root of the products of the half sum and three remainders by 160, and the quotient will be the acres, and the remainder divided by 40 will be the roods.

The same may be more readily done by logarithms, for as the addition of logarithms serves for

the multiplication of their corresponding numbers, and that the number answering to the half of a logarithm will give the square root of the number of that logarithm, it follows that half the sum of the logarithms of half the sum of the sides, and the three remainders will give the area, thus :

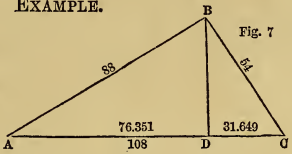
Half sum,	15.96	log.	1.20303
First remainder,	5.32	"	0.72591
Second "	3.68	"	0.56585
Third "	6.96	"	0.84261
			2)3.33740
Square four poles	46.63		1.66870

Or, 4.663
4
———
2.652
40
———
26.080 — A. 4, R. 2, P. 26 as before.

10th. When the three sides are given and the angles are required, call either side on which the perpendicular will fall from the opposite angle the base, then as the base is to the sum of the other two sides so is the difference of those sides to the difference of the segments made by the perpendicular, then half that difference added to half the

sum gives the greater, and substracted the less, by which means it is divided into two right angled triangles, the hypothenuse and one leg of each being given, the angles are easily found by plane trigonometry.

EXAMPLE.



Let A B C be any triangle having the sides given as follows, viz: A B 88, B C 54 and A C 108 to find the angles.

A B=88 Then as 108 : 142 :: 34
B C=54

142 sum
34 difference.

$$\begin{array}{r} 34 \\ \hline 568 \\ 426 \\ \hline \end{array}$$

108)4828.000(44.703 diff. of the segments at the base.
22.351 half diff.

$$\begin{array}{r} 432 \\ \hline 508 \\ 432 \\ \hline 760 \\ 756 \\ \hline 400 \\ 324 \end{array}$$

Then half the base 54+22.351=76.351, the greater segment A D, and 54—22.351=31.649 the less segment.

The triangle is now divided into two right angled triangles, the hypothenuse and base in each being given to find the angles, as follows:

As A B	88	1.9444827
: Rad.	90°	10.0000000
:: A D	76.351	1.8828147
		11.8828147
		1.9444827
: Sine A B D	60°.11′	9.9383320

And 90—60°.11′=29°.49′=Angle B A D. In the same way C B D is found to be 35°.53′ its complement 54°.07′=∠ B C D.

Now	A B D=	60°.11′
	C B D=	35 .53
Angle	A B C=	96 .04
∠	A=	29 .49
∠	C=	54 .07
		180 .00

Proof as the three angles of every plane triangle are equal to 180° per 32d of the 1st of Euclid.

11th. Many things occur to the practical sur-

veyor in the triangle, some of which I shall take notice of in this place. It often happens in practice that the two sides and their included angle are given to find the other angles and side.

RULE.—As the sum of the sides is to their difference so is the tangent of half the sum of the opposite angles to the tangent of half the difference; this half difference added to half the sum of the angles at the base gives the greater, and subtracted the less. Then as sine of either of the base angles is to its opposite side, so is sine of the contained angle to the required side.

EXAMPLE.

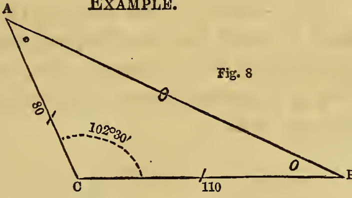


Fig. 8

Let A C =80, B C =110, and ∠ A C B 102°.30′ to find A B and the angles A and B.

Side B C	110	From	180
Side A C	80	take ∠ C=	102.30
Sum	190		2)77.30 sum of base angles.
Diff. of sides	30	½ sum =	38.45

Then as	190	log.	2.2787536	38°.45′
:	30	"	1.4771213	7 .13
:: Tag't	38°.45′		9.9044910	
				45 .58 ∠ A
			11.3816123	
			2.2787536	31 .32 ∠ B
:: Tag't of ½ diff.	7°.13′		9.1028587	

Then as sine B	31°.32′	9.7184971
: A C	80	1.9030900
:: sine C	102.30	9.9895815
Or its supplem't	77.30	
		11.8926715
		9.7184971
To A B	149.34	2.1741744

12th. Again, it often happens that the area must be found from the foregoing data, in that case multiply the two sides together, and that product by the natural sine of ½ the contained angle, gives the area.

EXAMPLE.

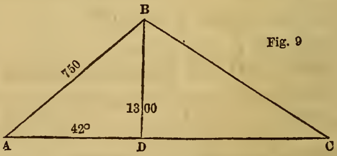


Fig. 9

Let A B C be a triangle having the side A C 13 chains, A B 7c. 50l. and ∠ B A C 42° to find the area.

$$\begin{array}{r} 7.5 \\ 13 \\ \hline 225 \\ 75 \\ \hline \end{array}$$

97.5×.334565 half the nat'l sine of 42°= 32.62 square four pole chains = $\overset{\text{A.}}{3}\ \overset{\text{R.}}{2}\ \overset{\text{P.}}{19.2}$ *Ans.*

DEMONSTRATION.

Let fall the perpendicular B. D.

A B : B D :: rad : sine A

$\therefore$ B D=$\dfrac{\text{A B}\times\text{sine A}}{\text{Rad}}$ But rad.=1.

$\therefore$ B D=A B=sine. Multiply each side by A C and B D. A C=A B. Sine A.×A C

But $\dfrac{\text{A C. B D}}{2}$–the area. Hence,

$\dfrac{\text{A B. A C. Sine A}}{2}$=area, which is the rule.

13th. Let B A C be a triangular farm, and P a well of water. It is required to draw a line or fence from the well that will divide the farm equally between two partners:

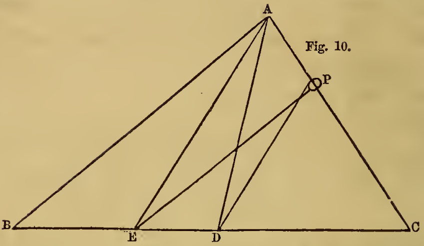


Fig. 10.

Find D the middle of the base, B C, and from P take a course of P D. Again set your instrument at A, and take the same course A E; cause a pole to be set at E, a line or fence from E to P will bisect the farm, which is easily demonstrated from the figure. See Bland.

14th. Again, suppose the well P, to be situated within the farm, and it be required to divide it equally between three occupants, so that each may have the use of the well.

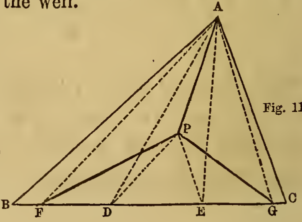


Fig. 11.

In fig. 11 divide the base B C, into three equal parts in D and E. Set your instrument at P, and take

the courses P D and P E. Remove your instrument to A, and take A F the same course as P D, and A G the same as P E. Cause stakes to be driven at F and E in a straight line between B and C. Fences from F, G, and A, to P, trisect the farm, which is plain from the figure.

15th. To find the area of a Trapezoid Rule, multiply half the sum of the parallel sides by the perpendicular distance between them, and the product is the area.

Let figure 12 be a Trapezoid; if A D be bisected in E, and E F drawn parallel to A B or C D, it also bisects B C in F.—Through F draw G H parallel to A D.

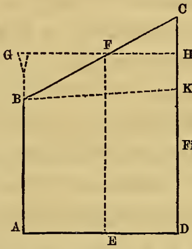


Fig. 12.

It is evident the triangles, B F G, and F C H, are similar and equal. (26th Euclid, 1st.) ∴ E F, half the sum of the sides, multiplied by the perpendicular distance between them, A D, gives the area.

Being surveying on the side of a bog, and wanting four acres to make up a division, and seeing A

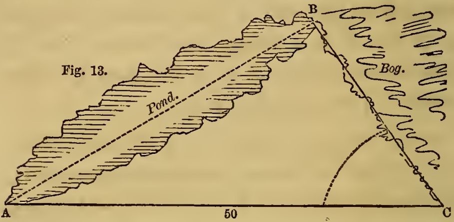


Fig. 13.

B would pass through a pond, I found A C fifty chains, and ∠ C 56°; how far must I measure from C towards B, so that the triangle A B C, may contain four acres.

Since A C × C B × ½ the natl. sine of 56°=4 acres, it follows that 4 acres divided by the product of one half the natl. sine of 56° into A C, gives B C the required side. Thus:

C
50×4=200 perches ×, 4145188=82.9; and 640 perches in 4 acres, divided by 82.9=7.72 per the length of B C, and in like manner any other similar case can be done.

17th. Sometimes it is found necessary to obtain the area of a trapezium from having the diagonals and the angle of intersection given.

Rule—Half the product of the diagonals multiplied by the natural sine of the angle of intersection, will be the area.

EXAMPLE.

If the two diagonals of a trapezium be 40.15, and 60.13 chains the ∠ of intersection 75° 45′, what is the area. ½ of 40.15×60.13=1207.1097= half the product of the diagonals, and 1207.1097× 96923=(natural sine of 75°45′)=1169.966934531= the area, in square four pole chains, or 116. 3. 39. 47. (A. R. P.) Answer.

18th. To find the area of a trapezium, when each side and the angle of intersection of the diagonals are given. *Rule*—Square each side of the trapezium; add together the squares of each pair of opposite sides; subtract the less from the greater; multiply the difference by the tangents of the angle of intersection. One fourth of the product will be the area.

EXAMPLE.

What is the area of a trapezium, the sides of which are 10, 13, 7.16, 8.32, and 10.05 chains respectively, and the ∠ of intersection of the diagonals 52° 15′.

$(10.13)^2 = 102.6169$

$(\ 8.32)^2 = \ 69.2224$

171.8393=Sum of sqs. of opposite sides.

$(15.05)^2 = 226.5025$

$(\ 7.16)^2 = \ 51.2656$

277.7681=Sum of sqs. of other sides.

105.9288 Difference,

Multiplied by .32288=$\frac{1}{4}$ the natural tangent,

34.20290944 or

A 3. 1 .27,23 perches.

For a demonstration of the foregoing, see *Gibson's Surveying, by Trotter.*

19th. To find the area of a trapezium, when the four sides are severally given, and also the sum of any two opposite angles. *Rule*—From half the sum of the four given sides, subtract each severally; multiply the four remainders continually together; from the result subtract one half the continual product of the four sides, multiplied by unity, increased by the natural cosine of the sum of the given angles. The square root of the result will be the area.

REMARK.

In the application of this theorem, it must be carefully remembered that the cosine of an angle is positive when that angle is in either the first or fourth quadrants, and negative when it is in the second or third quadrants. For a demonstration of this beautiful theorem, see also, *Gibson, by Trotter.*

N. B. When the sum of the opposite angles is 180°, that is, when the trapezium can be inscribed in a circle, the above rule is simply: from half the sum of the given sides, subtract each side severally; multiply the four remainders continually together, and extract the square root, gives the area.

EXAMPLE.

"One morning in May I went to survey,
As soon as bright Sol I espied;
I measured round a four cornered ground,
In the margin see the length of each side;
The angle at B, together with D,
An hundred and fifty degrees;
The meadow's content is all that I want,
Assist me kind youths, if you please."

A B 15.60
B C 13.20
C D 10.00
D A 26.00 ch'ns.

2)64.80 sum.

32.4=½ sum.

16.80=1st remr.
19.20=2d do.
22.40=3d do.
6.40=4th do.

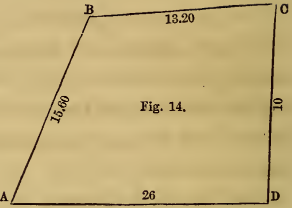


Fig. 14.

S=half the sum. of the sides.

Whence (s–A B)×(s–B C)×(s–C D)×(s–D A)= 32.4×16.8×19.2×22.4×6.4=46242.2016=46242. 2016

$$\frac{\text{And A B. B C. C D. D A.}\times(1+\cos.\ 150^\circ)}{2}$$

$$\text{That is } \frac{15.60\times13.20\times10.00\times26.00}{2}\times0.1339746=3586.4464$$

Difference=42655.7552

The square root of 42655.7552 is 206, 5327= area in square four pole chains, or 20. 2. 24,55232. (A. R. P.)

N. B. This problem is taken from Deighan's Arithmetic, vol. second, page 148, and the answer there given is 21. 2. 00,64 (A. R. P.), which is obtained by taking the trapezium to be inscribed in a circle, which is not the case.

When the opposite angles of a quadralateral are equal to two right angles, a circle can be described about it. The rule to find the area, then, is : multiply the half sum, and four remainders continually together, and extract the square root, for in that case $1+\cos.(A+B)=0$.

21st. To find the area of a circle having the diameter given. *Rule*—Square the diameter, and multiply by .7854, and you have the area.

22d. To find the area of an ellipsis. *Rule*—Multiply the transverse and conjugate diameters together, and that product by .7854, and you have the area.

23d. To find the area of a parabola. *Rule*—Multiply the height by the breadth, and take two-thirds of the product; you have the area.

24th. To find the area of a segment of a parabola. *Rule*—Multiply the base of the segment by the altitude thereof, and two-thirds of the product gives the area.

25th. To find the area of a field or lot, which is found to be the frustum or zone of a parabola, included by two parallel right lines, and the intercepted curves of the parabola. *Rule*—Add the two

parallel ends, divide the square of either of these ends by this sum, add the quotient to the other end, multiply this sum by the altitude of the frustum or distance of the ends, take two-thirds of the product, and it gives the area.

TRIGONOMETRICAL SURVEYING.

26th. It was not my intention to say any thing concerning this branch of surveying, as it is too extensive a subject for this small work; but as some young readers may not have met with any thing on that subject, I will present them with an outline of how that grand operation is conducted.

When an entire country, or part of a country, containing one or more counties is to be surveyed, it is done by triangulation, and the application of the rule given in the 12th section of this work. A line of some miles in length is measured and re-measured in order to prove its accuracy, on some plane or heath which is nearly level, first having been traced by a transit instrument, and poles placed in an exact straight line, to guide the measurers, as A B in the annexed figure, which is assumed as the base of the operations. A number of hills and elevated spots are selected, on which signals can be placed, suitably distant and visible

one from another. Thus, if A C D E B H G F, &c., be several objects, the situations of which

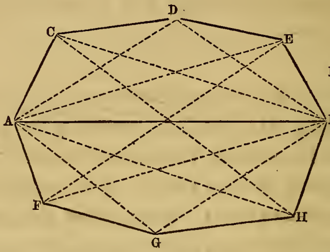


Fig. 15.

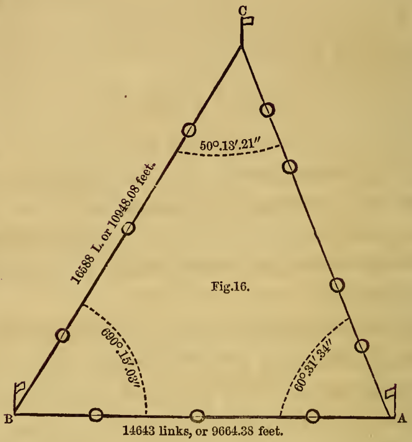
are to be laid down on a map, and they are within the lines, A C D E B H G F, accurately calculated. It is supposed that the stations A and B are chosen such as that all the others can be seen from each of them. Then from the extremity A, measure the angles E A B, D A B, C A B, &c., H A B, G A B, F A B, &c. And from the other extremity B, measure the angles, C B A, D B A, E B A, &c., F B A, G B A, H B A, &c. And as the common base, A B, and the several angles of all the triangles are now known, the sides, A C, A D, A E, &c. may be determined by simple proportion, for as the natural sine of

A C B : A B : : sine C A B : C B and so is sine A B C to C A, and so through all the triangles, the three sides being thus found in each triangle, the area is easily found, as shown in section 8th of this treatise. But to insure accuracy the objects C D E, etc., should be all intersected from some third station, ⊙ in the base A B, otherwise the figure may appear in the plotting to be right when it is not so, and there will be no means of knowing whether the angles have been correctly taken without going over the work again.

27th. Here follows an example of a triangle containing a mean area of $\overset{\text{A.}}{1135}.\overset{\text{R.}}{2}.\overset{\text{P.}}{12}.79$. The sides of which were traced by a transit instrument, and poles placed at the several points marked thus ⊙; this being done, the respective distances of the sides were ascertained by a mean of measures as follows, viz:

B A 14643 links, or 9664.38 feet, A C 17814 links, or 11777.24 feet, B C 16588 links, or 10948. 08 feet. The angles were taken by a theodolite as they are marked in the figure.

Now to determine the area of the triangle, A B C:



1st. From the data, A B, and the three angles of the known formula

$$\frac{A\,B^2 \times \text{sine } B \times \text{sine } A,}{2 \text{ sine } C.} = \overset{\text{A. R. P.}}{1135.2.27.18}$$

2d, by B C, and the three angles, the area will be 1135.3.029

3d, by C A, and the three angles, the area will be 1135.0.38.6

4th, by data A B, and the two adjacent angles, we have by the known formula,

$$\frac{A\ B^2 \times \text{sine } B \times \text{sine } A,}{2 \text{ sine } (B+A)}$$

	A. R. P.
The area will be	1135.2.25.7
5th, and by B C, and the two adjacent angles	1135.3.01.9
6th, by a similar formula from A C, and the two adjacent angles, the area will be	1135.0.37.99

7th, by data A B, and the adjacent angle A, and the remote angle C, we have by the known formula,

$$\frac{(A\ B)^2 \times \text{sine } A \times \text{sine } (C+A)}{2 \text{ sine } C.}$$ area, 1135.2.27.8

8th, by a similar formula from having A B, and the angles, B and C; area	1135.2.28.2
9th, by having C B and the angles, C and A; area	1135.3.03.58
10th, by having C B and the angles B and A; area	1135.3.04.38

11th, by a similar formula data C A, and the angles, C and B, gives the area	A. R. P.	1135.0.39.66
12th, by a similar formula from data C A, and the angles A and B; area		1135.1.00.12

13th, by data A B×B C, and the contained angle, we have

$$\frac{A\ B \times B\ C \times \text{sine } B}{2} = 1135.2.35.06$$

14th, by A C×A B, and the contained angle	1135.1.32.92
15th, by A C×B C, and their contained angle C	1135.2.00.79

16th, by data, A B×B C, and the angle, A, we have by a known formula, $\frac{B\ A \times \text{sine } A}{B\ C.} =$

$=\text{sine } C$, and $\frac{A\ B \times B\ C, \text{ sine } (A+C)}{2}$ area 1135.2.394

17th, by the application of similar formula to the data, A B×B C, and angle, C; area 1135.2.30.4

	A. R. P.
18th, by A C×C B, and angle, A,	1136.0.19.51
19th, by A C×B C, and angle, B, the area will be	1135.0.19.89
20th, by A C×B A, and angle, B, the area will be	1135.1.10.5
21st, by A C×B A, and angle, C, the area will be	1135.3.05.16
22d, by the usual rule from the three sides, s. s—a. s—b. s—c.	1135.2.14.7

Now the various data exhibited in this triangle have been ascertained with the same relative degree of precision; and the different areas deduced therefrom have been subjected to the same logarithmic process, till the figure has been exhausted; there is no reason to suppose that any one of them is nearer to the truth than another; and taking a mean of the results we have 1135.2.12.97 (A. R. P.) for the nearest approximation to the true area.

But suppose we consider the triangle as spherical, and the admeasurement of the sides as the lengths of three arcs of three great circles of the sphere; and, according to Sir Isaac Newton, the diameter of the earth to be 41,798,177 feet, we will then have, as the circumference of a great

circle of the earth is to 360°, so is the length of C B to the number of degrees or minutes, &c., contained in the arch, C B, viz:

As 131312964.37 : 360° :: 11757.24 : 1′.56″.03868=arch C A.
And do. : do. :: 9664.38 : 1′.35″.38309= " A B
And do. : do. :: 10948.08 : 1′.48″.05263= " B C.

Now let b a c, represent the sides of any spherical triangle, and e the spherical excess, we have by Lhuiller's theorem, Tangent $\frac{1}{4}$ E=

$$\text{Tan. } \frac{a+b+c}{4} \text{. tan. } \frac{a+b-c}{4} \text{. tan. } \frac{a-b+c}{4} \text{. tan. } \frac{-a+b+c}{4}.$$

And by restoring to a b and c, their determined values, we find

$$\frac{a+b+c}{4} = 0°\ .1'\ .19''.\ 8686$$

$$\frac{a+b-c}{4} = 0°\ .0'\ .32''\ .1771$$

$$\frac{a-b+c}{4} = 0°\ .0'\ .21''\ .8493$$

And, $$\frac{-a+b+c}{4} = 0°\ .0'\ .25''\ .8423$$

Whence the log. tangt. of 0° .1′ .19″ .8686=	6.5879531
of 0 .0′ .32″ .1771=	6.1931205
of 0 .0′ .21″ .8493=	6.0250065
of 0 .0′ .25″ .8423=	6.0979010
	2)24.9039811
Log. of $\frac{1}{2}$ the spherical excess=	2.4519905

The arc corresponding to this log. will be found

to be ,00584 parts of a second, consequently the spherical excess is 02336 of a second, and by a well known theorem, As 180° : the area of one-quarter the surface of the sphere : : the spherical excess to the area of the spherical triangle, viz:

As 180° 31500428420,3 the area of a great circle of the earth in statute acres : : 023360 to $\overset{\text{A.}}{1135}.\overset{\text{R.}}{2}.\overset{\text{P.}}{11}.3$ being $\frac{1}{2}$ perch less than the mean area, which is in defect, but should be in excess; but this is accounted for by the hills on the land not being taken into account; the difference, however, is insignificant, and shows that the difference between a plane and spherical triangle of considerable dimensions is very inconsiderable. See *Gibson's Surveying by Trotter.*

28th. How to measure a tract of land by measuring a base line through it, and not departing from that line, and yet finding all the distances round the land, their courses, and angles of the field, and the area, never before published.

In order to do this expeditiously, the surveyor should be provided with an instrument having two telescopes, one of which is movable, and the other fixed, by which he can at any time take half a right

angle from the base line, and also a right angle; he must also have an active assistant with a flag-staff, to hold at the corners as he proceeds with the measurement on the base line. Let A B C D E T M G H A be any tract of land that is to be surveyed, let the base K L, be traced through it with a transit instrument, and poles set perpendicularly, to be visible from one to another. Set your instrument at L, on the base line, which in this survey bears N 40 E. A theodolite and compass attached is the best instrument for this method; adjust your instrument, and let L be the point where 45° inflected from the base L K will cut the flag-staff; at the corner H, commence chaining towards K, and five chains you find 45° degrees deflected from the base line to the flag-staff at B, on the left, will bisect it, which note in your field-book by an oblique line to the left, making an angle as near 45° as the eye can judge; at 9.30 half a right angle to the right will cut a pole at G, and at 12.00 came the fence; at 13.20 half a right angle will cut C, and at $\overset{\text{C. L.}}{19.15}$ you find a right angle will intersect H. Now it is evident that you are $\overset{\text{C. L.}}{19.15}$ distant from H, for H 19.15. L

is an isosceles triangle, and ∴ you mark $\overset{\text{C. L.}}{19.15}$ on the perpendicular. The next perpendicular is at

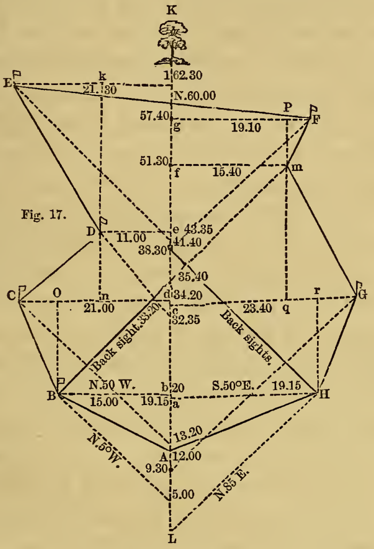


Fig. 17.

20, and the half right angle having been taken at $\overset{\text{C.}}{5}$ on the chain line, 20—5=15=the distance to B. Again at $\overset{\text{C. L.}}{32.35}$ you find half a right angle bisects

the pole at D, and at 33.20 a right angle intersects at G, and 33.20—9.30=$\overset{\text{c. l.}}{30.40}$=the length of the perpendicular which set on it. At 34.20 you find the next perpendicular on the left to C, and the one-half right angle having been taken at 13. 20 .·. 34.20—13.20=$\overset{\text{c. l.}}{21.00}$ the distance to C; proceeding in this way you have 43.35—32.35=11 chains to D, and 51.30—35,40=15.40=the distance to M, and 57.40—38.30=19.10 to F, and 60—57.40=2.10=the perpendicular of the last △ within the fence on the right and 62.30—60=2.30= the perpendicular without the fence; also, 62.30—41=21.30=the distance to E, which △ is to be ducted out of the area of the last trapezoid on the left. Thus you have found with very little trouble all the requisites for calculating the area of the land, and it may be remarked, that you might have commenced at the corner B and noted where the two perpendiculars fell at 19.15 and 20 and as you proceeded on your base line take back sights at the proper distances to intersect the poles at B and H, and the distances from where the perpendiculars would fall to these several points would be the chains and links to be placed thereon. The dis-

tances all round the land, can be accurately found, for in the present case $\surd(A\ a^2)+(a\ H^2)=\ A\ H$, and r G, and r H being given $\surd(r\ G^2)+(r\ H^2)=H\ G$ and so on all round the land, and seeing that the courses of A a and a H are given, the course of A H may be readily found, for having the distance and difference of latitude and departure, the course is given in the tables; also, the internal angles can be easily found, for in the $\triangle$ A a H A a : Rad. : : a H : tang't a A H, and so with the $\triangle$ B b A. Hence, the angle B A H, is known, and it is evident the same holds good all round the land, the bases and perpendiculars of all the right angled triangles being found from the base line and can be marked on the sketch as the surveyor proceeds. The same may be done with a good compass, for having the course of the base line, the courses of the normals to right and left are known, and the course of $\frac{1}{2}$ a right angle being once ascertained on the right and left of the base will always serve to find the points on the base where they are to be taken; but this would require many trials and waste time, whereas, an instrument showing $\frac{1}{2}$ a right angle will save much time.

Thus, in a plane country, the scientific reader will acknowledge the plan completely available, and the surveyor can calculate the content of the land on the margin of his book while his needle is settling, and be able to answer the farmer satisfactorily, who thinks a surveyor should be able to tell the content the moment he has the last distance measured.

The plotting and calculation of a survey taken on the above plan is so obvious as to require no explanation, seeing all the figures are either right angled triangles or trapezoids, to find the area of which is shown in figure 12th.

29th. The most correct method of correcting the difference of latitude and departure in surveys taken with the compass, to fit them for calculation, some authors divide the differences proportionally among all the stations; but as there may be some stations in a survey really correct, any alteration in them would make them incorrect, so that the altering of the legs of stations in surveys where land is of great value, is a matter of considerable importance.

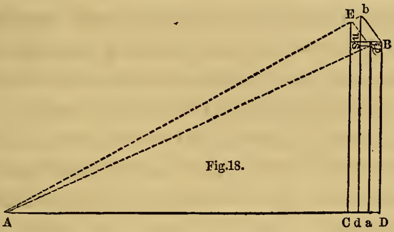


Fig.18.

PROBLEM.

To find what may be the error in the difference of latitude and departure of a given station arising from the inaccuracy of practice:

Let the right angled triangle A B D, fig. 18th, represent a station with its difference of latitude and departure; if the angle A be the bearing, then will the leg A D, be the difference of latitude, and the leg B D, the departure; but if the angle at B be the bearing, then will the leg B D, be the difference of latitude, and D A the departure. Let the small angle B A b represent the error committed in taking the bearing, which may amount $7\frac{1}{2}$ minutes, and the small part B e or E b, the error committed in chaining, in proportion to the whole line A B, or A e, as 0.5 is to 5.00, (for in measuring the

length of lines, there may be an error committed of half a link in 10 chains; (this is found by experience), and let e a, b d, and E c be drawn parallel to B D, and B n o, and r e s, parallel to D A.

Case 1*st*. Suppose A B to be the true bearing and length of a station, and A b the one found by observation. Now it is plain that instead of the triangle A B D, we shall have by observation the triangle A b d, so that there is an error of the quantity n b, by which the leg B D is increased, and an error of the quantity B n, by which the leg A D is decreased, and the contrary may be supposed, if A b be the true distance and bearing and A B that found by observation; but when the angle at A is very small, D d may be supposed equal to (O).

Case 2*d*. Suppose the true length and bearing of a station to be A e, and that found by measurment to be A B the bearing exact. Now it is plain that the leg e a is increased by the error r B, and that the leg A a, is increased by the error r e or a D, and the quantities or errors by which each leg is increased are in proportion to the legs

themselves, that is, B r : e a : : r e : A a, and as B e is to A e.

Case 3d. Suppose A e the true bearing and length of a station, and A b the same, found by observation. This supposes a compound error both in chaining and bearing, and that the error in the bearing increases the smallest angle in respect of the bearing and its complement. Here we see that when the leg A a is increased to A D by the error in chaining, as in the last case, it shall, at the same time, be brought back to A d by the error in the bearing, as in case 1st. Therefore, the leg A a will be increased by the quantity r e—B n, or decreased by the quantity B n—r e; but r e is greater than B n, when the angle at A is small; and B n is greater than r e, when the angle is near 45°; for they become equal when the angle is about 25°; but at the same time the leg e a will be increased to d b, by the error b S=b n+B r.

Case 4th. Suppose A E the true distance and bearing, and A B that found by observation; this supposes the error in the bearing to decrease the smallest angle. Now it is evident that the longer leg A c is increased by the error B o or D c, and

the shorter leg decreased by the error E o. But B o=B n+r e (for r e=n o) and E o=b n—B r. These errors are easily found in numbers by considering the figure, and that they are always proportional to the length of the stations.

Here follows a table of errors in links and decimals, calculated for a station of 30 two pole chains, and for the different angles and their complements, under which they are placed, but which can be changed to any other length, by altering them in the same proportion as are the stations.

B A b=½° error in bearing.	2° / 88	12° / 78	23° / 67	32° / 58	42° / 48	45°	B e 1.5 links error in chaining.	
b n=	3.2	3.1	3.0	2.8	2.4	2.3	Error in short Leg.	Case
B n=	0.0	0.7	1.4	1.7	2.2	2.3	Error in long Leg.	1st.
B r=	0.0	0.3	0.6	0.8	1.0	1.0	Error in short Leg.	Case
r e=	1.5	1.5	1.4	1.3	1.1	1.0	Error in long Leg.	2d.
b s=(b n+B r)	3.2	3.4	3.6	3.6	3.4	3.3	Error in short Leg.	Case
a d=(B n∽r e)	1.5	0.8	0.0	0.4	1.1	1.3	Error in long Leg.	3d.
E o=(b n–B r)	3.2	2.8	2.4	2.0	1.4	1.3	Error in short Leg.	Case
B o=(Bn+r e)	1.5	2.2	2.8	3.0	3.3	3.3	Error in long Leg.	4th.

CORROLLARY.

Hence we may adopt the following rules for altering the legs of stations in the correcting of surveys:

Rule First.

When the course, or angle, is either great or small; or when the difference of latitude and departure are found in the beginning of the tables, then the shortest leg may be increased or decreased by any quantity not greater than 3.2 links, and the longest leg increased by any quantity not greater than 1.5 links.

Rule Second.

When the latitude and departure are found about the middle of the tables, or when the angle is about 20° under or over 45°, then the shortest leg may be increased by any quantity not greater than 3.6, or rather 4 links, and the longest leg left unaltered, which is, when the error in the bearing increases the angle opposite the smallest side; but when contrary, the longer leg may be increased by any quantity not greater than 3 links, and the shorter leg decreased by 2 links.

Rule Third.

When the difference of latitude and departure are found in the latter part of the tables, or when the bearing is about 45°, then either of the legs

(they being nearly equal) may be increased or decreased by any quantity not greater than 3 links, and the other leg by 1.4 links, but when one leg is increased the other must be decreased.

These rules are on the supposition that the chaining is always too long, which, in practice, I have nearly always found to be the case; but when a surveyor has reason to think otherwise, he may alter the rules to his opinion, not only in respect to this, but also relative to the quantity of the errors.

A description of an instrument by which any person, though unskilled in surveying, may measure a map, or part of a map, almost at one view:

Get a piece of good glass about 8 or 9 inches long, and 6 or 7 inches broad, and divide it into small oblong rectangles of eight-tenths of an inch by 5 five-tenths, as fig. 19th. By laying this instrument (which I call a *computor*) on a map you can tell with very few figures, sometimes with the eye only, how many of the rectangles are contained in the map, and consequently, how many acres. When the map is laid down by a scale of 20 perches to an inch, then each rectangle will be

16 perches by 10, or one acre; and if the map be 40 perches to an inch, then each rectangle will be 32 perches by 20, or 4 acres; and if by 80 perches to an inch, then each rectangle will contain 16 acres. This instrument would be useful to gentlemen and others not very well skilled in surveying, to measure a map, or part of a map that they wished to know the content of nearly. It is easily used. The sides of the glass must be made to coincide with as many of the lines on the map as possible, and the broken squares can be estimated by the eye, or a square inch horn.

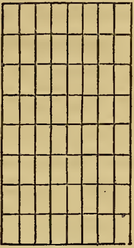


Fig. 19.

Description and design of a new instrument by which distances can be found at once, without any calculation:

Let a brass semi-circle (fig. 26) of about 9 inches radius, have its inner edge or limb, divided into 90 equal parts, beginning at N and counting upwards 10, 20, 30, &c., to 90 at Z, and each of these divisions subdivided into 6 equal parts. Let

the outer limb be divided into degrees and 6th parts of a degree, marking the degrees from the middle of the limb, both ways, 10, 20, 30, &c., to 90 at N and Z. Let also, the middle space between the outer and inner limbs, be marked from Z to N, 10, 20, 30, 40, &c., to 180 at N.

Let this semi-circle be fixed to the middle of a box ruler B D, about $3\frac{1}{2}$ feet long, an inch and a half broad, and of a convenient thickness. The inner breadth of half this rule must be level with the surface of the semi-circle, but the outer half must be higher about two-tenths of an inch. On the outer half there must be fixed a thin brass scale of an equal length and breadth with the box ruler, the breadth of which scale is to be divided, by lines drawn from end to end, into three equal parts, and the length into inches, half inches, and tenth of an inch; the inches are to be drawn directly across the whole breadth, and marked 1, 2, 3, 4, &c., both ways to B and D; the half inches are to be drawn across the middle and innermost third, and the 10ths only across the inner third. Let there be on one end of this scale an inch, and on the other end half an inch, each divided very

exactly into 10 equal parts diagonally, that the 10ths and centesms which may happen in the operations, on the square and indices hereafter to be described, may be exactly measured on them by a pair of dividers. The reason for raising the outer half of the box ruler above the inner half two-tenths of an inch, is to make room for the indices A b and A d, which are to be fixed to the centre of the semi-circle, and there to open and shut as occasion requires, like the legs of a sector. Those indices are about 26 inches long, three-fourths of an inch broad, and about two-tenths thick; their breadth is to be divided into three equal parts, and their length into inches, half inches, and tenths, as the brass scale before mentioned. The inches are to be marked from the center A, with 1, 2, 3, 4, &c., to b and d, and the tenths drawn across the inner third. Each of those indices must have a small screw nut with a pin or bit of wire upon it, which pin may, by the screw nut, be fixed exactly to any division on them in order to suspend the label, or ruler T Y, which has a thin piece of brass with a small hole in it, exactly fitting the aforesaid pin, and is to be fixed

also to any division of the ruler, as occasion requires. Let this label, or ruler, be about two feet long, and of the same breadth and thickness as the indices A b and A d, and divided after the same manner as they are, only the tenths are to be drawn across the inner edge, as well as across the inner third of the breadth, and the inches are to be marked 1, 2, 3, 4, &c., from C to T and Y, making C T eighteen inches, and C Y six. The like divisions are to be made on the side of the square K X, beginning at the inner edge of the brass ruler at K, marking the full inches on the upper side, 1, 2, 3, 4, &c., to 24; the tenths are to be drawn across the upper third and the upper edge. Let this instrument be fixed on a tripod with a ball and socket like those of a common surveying instrument, but very strong, in order to have it very firm; and let there be sights which may, as occasion requires, be fixed on the diameter, indices, and ruler T Y, of the the same kind with those of a surveying instrument.

N. B. The ball and socket must not be fixed exactly under the center of the semi-circle, but some distance from it, on the cross-bar which goes from

the center to the middle of the limb, as well to support the head of the instrument more easily by being nearer its center of gravity, as to make room for an air level, which must be fixed exactly under the diameter or ruler A B, so that when the semicircle is turned vertically the diameter may be fixed horizontally.

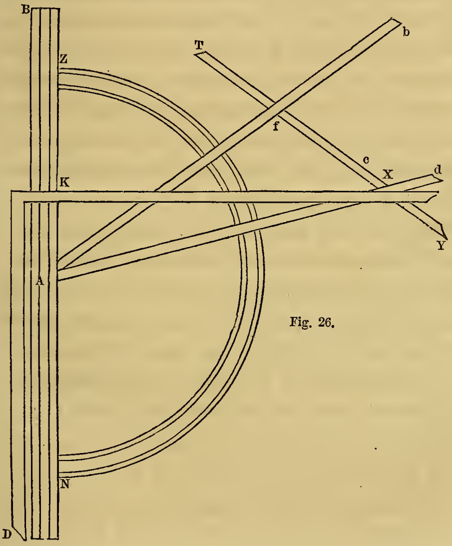


Fig. 26.

The use of the Instrument in measuring distances:

EXAMPLE.

Let it be required to find the distance from the house at A to the castle, (fig. 27) or to any part thereof, as the weather-cock on the top of the spire at C.

Having set up your instrument at A, turn it about till through the sights on the diameter, you see a mark set up at B, and having fixed the diameter in that position, turn the moving index till through the narrow slit of a small sight fixed on the center, you see the hair in the other sight cut the spire at C, then fixing the index in that position to the limb of the semi-circle, measure with a four pole chain in a straight line from A to B; and having marked the chains and links of that distance on the diameter and placed the ruler with the sights on it exactly to that distance, by means of the small pin and hole mentioned before, set up your instrument at the end of the distance you measured (which you may make full chains if you please) and turn it about till through the sights on the diameter you see a pole at the first station A, and having fixed it in that position, turn the ruler on the pin which is fixed at the former distance on

the diameter, till through the sights on it you see the vane at C; then will the part of the index a c, cut by the inner edge of the ruler, give the distance A C from the house to the spire at C, which was to be found; and if there be occasion, the distance from the mark at B to the spire will be found on the ruler at the intersection of the index; all of which is plain from the similarity of the triangles A B C and a. pin. c, or that formed by the diameter, index, and ruler, from Cor. 1st 4 Euc. Book 6th. Thus the surveyor can find the distance of any or all the particular objects he can see and may wish to set down in his map, and by turning the instrument vertically by means of a notch in the socket, inaccessible heigths can, in like manner, be readily ascertained in the same manner.

EXAMPLE IN MEASURING DISTANCE.

Let it be required to find the distance from the house at A to the castle, (fig. 27) or to any part thereof, as the weather-cock at the top of the spire at C.

Having set up your instrument at A, turn it about till through the sights on the diameter, you see a pole at B, and having fixed the diameter in

that position, turn the moving index till through the narrow slit of a small sight fixed on the center, you see the hair in the other sight cut the spire at C; then fix the index in that position to the limb of the semi-circle and measure with your chain of 100 links in a straight line from A to B, which mark on the diameter, and place the ruler, having the sights on it exactly on that distance by means of the small pin and hole before mentioned; set up the instrument at the end of the measured distance, and turn it about till through the sights on

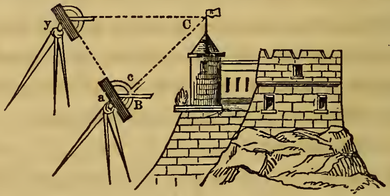


Fig. 27.

the diameter you bisect the pole at A, and having fixed it in that position, turn the ruler on the pin which is fixed at the former distance on the diameter, till through the sights you see the vane at C; then will the part of the index, a c, cut by the in-

ner edge of the ruler, give the distance A C from the house to the spire at C.

And in like manner by directing the ruler to any other objects from A, and noting the degrees cut by the ruler on the limb, and directing from B to each object, the distance from A will be shown as before explained, and thus the surveyor furnished with such an instrument, can from the end of his first station, tell the length of his diagonals to as many corners as he can see from that point. Also, by turning the instrument vertically, heights can be determined in the same manner.

I would recommend the surveyor to use a compass, having the limb divided into 360°, and the bottom of the box into four 90's; then in taking the courses, if N. W., the limb and quarter compass are the same; but if in the S. W. quarter, the sum of the degrees on the limb and quarter compass are 180°; and in S. E. quarter, the difference of the degrees on the limb and quarter compass make 180°; lastly, if in the N. E. quarter, the sum of the quarter compass and limb make 360. A surveyor should prove all his courses by this rule before he quits his instrument.

PROBLEM.

Given the bearings of any two stations of a survey, thence to determine the angle made by those stations. *Rule*—Deduct the preceding bearing from the succeeding, according as the remainder is greater or less than 180°. Add—or+180° (as the case may be) and you have the required angle.

N. B. The angle found by the above rule will be internal if the polygon lie towards the right hand in the traverse; and external, if toward the left.

EXAMPLE FIRST.

Required the several angles of the polygon A B C D E F G, the courses of the sides being, viz:

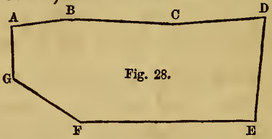


Fig. 28.

1	A B	269½°	or	S. E.	89½°
2	B C	251½	or	S. E.	71½
3	C D	252¾	or	S. E.	72¾
4	D E	162¼	or	S. W.	17¾
5	E F	77¾	or	N. W.	77¾
6	F G	30¾	or	N. W.	30¾
7	G A	5¾	or	N. W.	5¾

From $251\frac{1}{2}$
take $269\frac{1}{2}$

-18
$+180$

Sum 162=Ang. A B C.

From $77\frac{3}{4}$
take $162\frac{1}{4}$

$-84\frac{1}{2}$
$+180$

Sum $95\frac{1}{2}=\angle$ D E F

From $252\frac{3}{4}$
take $251\frac{1}{2}$

$+1\frac{1}{4}$
$+180$

Sum $181\frac{1}{4}=\angle$ B C D.

From $30\frac{3}{4}$
take $77\frac{3}{4}$

-47
$+180$

Sum $133=\angle$ E F G

From $162\frac{1}{4}$
take $252\frac{3}{4}$

$-90\frac{1}{2}$
$+180$

Sum $89\frac{1}{2}=\angle$ C D E.

From $5\frac{3}{4}$
take $30\frac{3}{4}$

-25
$+180$

Sum $155=\angle$ F G A

From $269\frac{1}{2}$
take $5\frac{3}{4}$

Rem. $263\frac{1}{2}$
-180

Sum $83\frac{1}{2}=\angle$ G A B

Now 180° multiplied by the number of sides

any polygon minus 360°, equals the sum of the internal angles $\therefore$ $180 \times 7 = 160$ and $1260 - 360 = 900$ So $83\frac{3}{4}+162+181\frac{1}{4}+89\frac{1}{2}+95\frac{1}{2}+133+155=900°$. Proof.

Next. Having the bearing of any station and all the internal angles of any polygon, thence to determine the courses of each of the other stations in the regular order of succession, viz: the land lying to the right hand as you surround it. *Rule:* According as the given angle is+or—than 180°; add the preceding bearing, succeeding angle, and +or—180° (as the case may be;) their sum will be the succeeding bearing or course.

NOTE.—It sometimes happens that the result will be more than 360°; in this case take 360° from it and the remainder will be the course of the succeeding station.

EXAMPLE.

Take the course of A B $269\frac{1}{2}$ or S. $89\frac{1}{2}$ E, in the preceding figure, and the angles as there found, viz:

$269\frac{1}{2}$
162
+180
$611\frac{1}{2}$
Deduct 360

Cou. of B C $251\frac{1}{2}$ or S $71\frac{1}{2}$ E.

$251\frac{1}{2}$
$181\frac{1}{4}$
−180

Cou. of C D $252\frac{3}{4}$ or S $72\frac{3}{4}$ E.

$252\frac{3}{4}$
$89\frac{1}{2}$
+180
$522\frac{1}{4}$
Deduct 360

Cou. of D E $162\frac{1}{4}$ or S $17\frac{3}{4}$ W.

$162\frac{1}{4}$
$95\frac{1}{2}$
+180
$437\frac{3}{4}$
360

Cou. of E F $77\frac{3}{4}$ or N $77\frac{3}{4}$ W

$77\frac{3}{4}$
133
+180
$390\frac{3}{4}$
360

Cou. of F G $30\frac{3}{4}$ or N $30\frac{3}{4}$ W

$30\frac{3}{4}$
155
+180
$365\frac{3}{4}$
360

Cou. of G A $5\frac{3}{4}$ or N. $5\frac{3}{4}$ W.

$5\frac{3}{4}$
$83\frac{3}{4}$
+180

Cou. of A B $269\frac{1}{2}$ or S $89\frac{1}{2}$ E.

being the same as that given; therefore, a proof of the correctness of the work. And thus the surveyor has a sure method of avoiding the inconvenience of the needle being drawn from its true position by mines or other causes, and also correct the diurnal variation; for no matter how much

the needle may be attracted at any station, the angle will be correct by taking a back and fore sight at every station, and having the true course of the first station. All the others can be found by the foregoing rules. And to know if any attraction exists at the first station, take a course in a different direction from your chain line; go to the object bisected, or to some convenient distance in that direction, and take a back sight; if that agree with the fore sight, you may safely conclude that no attraction exists at either; but should it differ, make trial in some other direction, in like manner, till you find what station the attraction is in; but by using a good theodolite all such trouble is avoided.

In every survey that is truly taken, the sum of the Northings is equal to the sum of the Southings, and the sum of the Eastings to the sum of the Westings.

Let a b c e f g h represent a plot or parcel of land; let a be the first station, b the second, c the third, and so on. Let N S be a meridian line, then will all lines parallel thereto, which pass through the

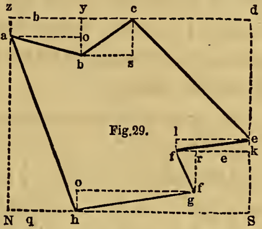


Fig.29.

several stations, be meridians also, as a o, b s, c d, &c., and the lines b o, c s, d e, &c., perpendiculars to these, will be east or west lines or departure. The northings e i+g o+h g=a o+b s+c d+f r, the southings; for let the figure be completed, then it is plain that g o+h g+r k=a o+b s+c d and e i—r k=f r; if to the former part of this first equation e i—r k, be added, and f r to the latter, then g o+h g+e i=a o+b s+c d+f r; that is, the sum of the northing is equal to the sum of the southings.

The eastings c s+q a=o b+d e+i f+r g+o h, the westings for a q+y o (a z)=d e+i f+r g+o h, and h o=c s—y o. If to the former part of this first equation c s—y o, be added, and b o to the latter, then c s+a q=o h+d e+i f+r g+o h; that is, the sum of the eastings is equal to the sum of the westings.

Now, as there is many methods of calculation, and every man chooses one in preference to all

others, I shall here show the method which I have always practiced, being, I think, least liable to mistakes, although not the shortest, as shall be hereafter shown.

No. of station.	Course.	Distance. Chs. Lks.	N.	S.	Lat. 11.00	Lats. added	E. area.	W. area.	E.	W.
1	N. 63½ W.	2.24	1.00	......	12.00	23.00	....	46.0000	......	2.00
2	N. 56¼ E.	3.60	2.00	......	14.00	26.00	78.0000	....	3.00	......
3	N. 26½ E.	2.24	2.00	......	16.00	30.00	30.0000	....	1.00	......
4	S. 71½ E.	3.16	......	1.00	15.00	31.00	93.0000	....	3.00	......
5	S. 26½ E.	2.24	......	2.00	13.00	28.00	28.0000	....	1.00	......
6	S. 71½ W.	3.16	......	1.00	12.00	25.00	....	75.0000	......	3.00
7	S. 45 E.	1.41	......	1.00	11.00	23.00	23.0000	....	1.00	......
8	S. 63½ E.	2.24	......	1.00	10.00	21.00	42.0000	....	2.00	......
9	N. 45 E.	1.41	1.00	......	11.00	21.00	21.0000	....	1.00	......
10	S. 26½ E.	2.24	......	2.00	9.00	20.00	20.0000	....	1.00	......
11	S. 45 W.	1.41	......	1.00	8.00	17.00	....	17.0000	......	1.00
12	S. 63½ W.	2.24	......	1.00	7.00	15.00	....	30.0000	......	2.00
13	N. 45 W.	2.83	2.00	......	9.00	16.00	....	32.0000	......	2.00
14	S. 63½ W.	2.24	......	1.00	8.00	17.00	....	34.0000	......	2.00
15	N. 26½ W.	3.16	3.00	......	11.00	19.00	....	19.0000	......	1.00
			11.00	11.00	......	......	....	....	13.00	13.00

Sum of the East areas,	335.0000	253.0000
Sum of the West areas,	253.0000	
	2) 82	
	41	The content.

In the above method the northings and southings, eastings and westings, being corrected by the

foregoing rules, set the sum of the northings, or southings at the top of the column titled latitude, then continually add the northings and subtract the southings, or add the southings and subtract the northings, and the last number will always be the same as the first, which is a proof of so much of the work. Then add the first and last latitudes together, and place their sum opposite to the first station in the column under latitudes, added, and so continue to add every two adjoining latitudes, and place their sum in a line with the latter, then multiply each of these numbers by the particular easting or westing belonging to that station, and place the product in the column of east or west area, as the case may be, and the difference of these two columns divided by two, will be the content of the survey. In this method there is no danger of making mistakes from indirect stations, and by using the eastings, and westings, in the same manner as you did the northings, and the southings, you can prove the work, and find the area four different ways.

ANOTHER METHOD, WHEREIN FEWER FIGURES ARE USED, NEVER BEFORE PUBLISHED:

The Eastings and Westings, Northings and Southings, are here corrected according to the foregoing rules, and placed as usual, as follows:

CALCULATION OF THE NOTES ON THE SUCCEEDING PAGE.

	N.	S.	L. N.	L. S.	Lats. added.	Doub. Semi Rectangle.	E.	W.	
1	....	2.76	2.76	......	2.76	+4.4712	1.62	......	
2	....	4.44	7.20	5.15	9.96	+11.9520	1.20	Ex.E	
3	....	0.77	......	4.38	9.53	+20.5848	......	2.16	
4	Ex. S.	4.38	......	0.00	4.38	— 1.9272	0.44	......	Indirect.
5	2.60	....	......	2.60	2.60	14.3520	......	5.52	
6	0.36	....	......	2.96	6.56	—10.3416	1.86	......	Indirect.
7	3.35	....	6.04	6.31	9.27	+59.1426	Ex.W	6.38	
8	3.34	....	2.70	......	8.74	+17.4800	2.00	......	
9	2.11	....	0.59	......	3.29	—4.4086	......	1.34	Indirect.
10	....	0.40	0.99	......	1.58	+5.6564	3.58	......	
11	....	2.53	3.52	......	4.51	+5.4120	1.20	......	
12	1.75	....	1.77	......	5.29	+5.0784	0.96	......	
13	1.77	Ex. N.	0.00	......	1.77	+4.4958	2.54	......	
	15.28	15.28				165.3026	15.40	15.40	

Double the sum of the indirect, 33.3548

131.9478

65.9739 Angular spaces.

```
     11.76 Parallel breadth.
     12.35 Meridianal breadth.
    ------
      5880
     3528
    2352
   1176
   -------
  145.2360 Content of parallelogram.
   65.9739
  --------
   7,9.2621
          4
  ---------
   3.70484
        40
  ---------
   28.19360
```

A. R. P.
7.3.28.19, the same as on next page.

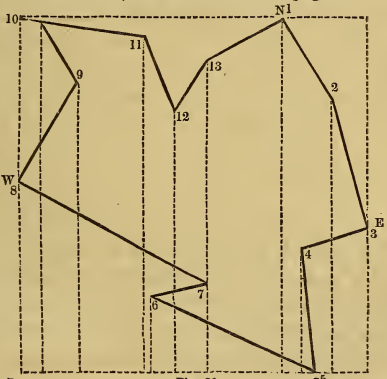


Fig. 30.

The foregoing plot and calculation may not be unacceptable to the reader, being as complicated a figure as could be easily met with.

A new and concise method of Calculation, wherein fewer figures are used than in the common methods:

	N.	S.	E.	W.	M. D. 162	D. D.	Area.	Deduction.
1	....	2.76	1.62	....	3.24 E.	4.86 E.	13.4136	....
2	....	4.44	1.20	....	4.44 E.	7.68 E.	34.0992	....
3	....	0.77	....	2.16	2.28 E.	6.72 E.	5.1744	....
4	....	4.38	0.44	....	2.72 E.	5.00 E.	21.9000	....
5	2.60	....	....	5.52	2.80 W.	0.08 W.	2080	....
6	0.36	....	1.86	....	0.94 W.	3.74 W.	1.3464	....
7	3.35	....	....	6.38	7.32 W.	8.26 W.	27.6710	....
8	3.34	....	2.00	....	5.32 W.	12.64 W.	42.2176	....
9	2.11	....	....	1.34	6.66 W.	11.98 W.	25.2778	....
10	....	0.40	3.58	....	3.08 W.	9.74 W.	....	3.8960
11	....	2.53	1.20	....	1.88 W.	4.96 W.	....	12.5488
12	1.75	....	0.96	....	0.92 W.	2.80 W.	4.9000	....
13	1.77	....	2.54	....	1.62 E.	0.70 E.	....	1.2390
	15.28	15.28	15.40	15.40			176.2080	17.6838
							17.6838	

2,0)15,8.5242

7,9.2621
4

3,7.0484
40

28.19360

A. R. P.
7 3 28.19

This method may be called a compound of Burgh's and Gibson's, without being intimately connected with either. It allows the first meridian to pass at any distance from the first station not less than the first latitude or first departure.

This example supposes the first meridian to pass at the distance of the first Easting from the first station of the survey, and the M. D. column is completed by one single addition of the Eastings, or one single subtraction of the Westings, to or from each preceding one, agreeably to the nature of the signs. The D. D., or double distance column, is completed by adding the first and last, and placing their sum in a line with the first Easting or Westing, and then adding every two according to the signs, and placing their sum in a line with the latter, marking E. or W. as the case may be. Then the Eastings × by the Southings, and the Westings × by the Northings, must be put into the area column; but, the Westings × by the Southings, and the Eastings × by the Northings, must be put into the deduction column, the difference is double the area of the survey.

The following is a method of calculation first published by Noble, the inventor, and is a very superior plan when well understood, but requires considerable attention to distinguish the indirect stations, as the areas belonging to them must be deducted. A little practice will enable the learner to know both them and the four extremes, viz:

N. S. E. and W. That author's description of a semi-rectangle is a figure limited by the latitudes of both ends of the station, the station itself, and a section of the parallel from which the latitudes are measured, equal to the departure; and when the last mentioned is indirect, the semi-rectangle is indirect also, viz: Indirect or retrograde stations are those stations, in respect of the rest, which bear backward or contrary to the natural succession of the four quarters of the compass.

If, in proceeding Southerly from the extreme point North, there happen a station to turn Northerly, or, in proceeding Northerly from the extreme point South, there happen a station to turn Southerly, such stations are indirect or retrograde stations. The same may be said of stations that turn after the like manner in proceeding from the extreme points E. and W. of the survey. The extreme points, N. S. E. or W. of a survey, are the ends of those stations which run more to the N. S. E. or W. than any other stations in the survey.

Though most surveys have those four extreme points, yet there are some where one and the same station may be the greatest extreme N., and at the same time the greatest extreme East or West;

or one and the same station may be the extreme South, and likewise the extreme East or West. The circumscribing parallelogram of a survey is a rectangle or parallelogram circumscribing the body of the land, whose four sides, passing through the four extremes N. S. E. and W. of the survey, are two meridians and two parallels of latitude.

The angular spaces are the areas contained between the sides of the circumscribing paralellogram, and the stations of the land surrounded, which, deducted from the area of the second parallelogram, leaves the content of the survey.

Now in order to find the area of those angular spaces, the four extremes must first be ascertained. This an experienced hand can see at once by examining his field-book, which, being known, you must find the latitude of each station in the survey from the extreme points North and South; thus, having found and corrected your latitudes and departures, and placed them as in the following table, write O in a line with N, and also the South extreme as in the following table. Now, beginning at each of these extremes, North and South, continue to add the Northings, and subtract the Southings to find the latitude of each station to

the extreme point West, but you must still add the Southings and subtract the Northings to the extreme point East. When the latitude of every station is thus found, and placed in their proper columns, add every two latitudes next each other, and put their sum in a line with the latter station in the column marked L. A., and each sum or number in this column is the length of a rectangle, which is double the semi-rectangle of each station. It is no matter at which of the two latitudes you begin, so that you place their sum in a line with the latter or succeeding station; but it is common to begin by adding the first and last stations together, and placing their sum in a line with the first station; then add the first and second, and place it in a line with the second, and so on till the column is filled. Then each number must be multiplied by its corresponding Easting or Westing, and the products put in the column marked D. S., or double semi-rectangle of each station. If the Easting or Westing be direct, then this product must be marked +; but if it be indirect, with the negative sign —, and the sum of all the affirmatives, abating the sum of all the negatives, will be the content of all the angular

spaces. But, to find the length and breadth of the circumscribing parallelogram, note that from the sum of all the Northings or Southings you must deduct the sum of all the Northings or Southings that have indirect difference of latitude, which will give one side, and the same must be done with the Eastings and Westings to find the other side. The length and breadth of the parallelogram being thus found, they must be multiplied together, and from their product take the content of the angular spaces, and the remainder will be the content of the survey.

TAKE THE FOLLOWING EXAMPLE IN NUMBERS.

	N.	S.	L. N.	L. S.	L. A.		E.	W.
1	....	5.75	....	0.00	5.75	+076.5900	....	13.32
2	30.28	....	....	30.28	30.28	+468.7344	....	15.48
3	9.23	....	....	39.51	69.79	+687.4315	....	9.85
4	9.04	....	6.17	48.55	88.06	+626.1066	....	7.11
5	4.66	....	1.51	....	7.68	+088.9344	11.58	....
6	1.51	....	0.00	....	1.51	+020.2340	13.40	....
7	....	6.78	6.78	....	6.78	+049.8330	7.35	....
8	....	17.46	24.24	....	31.02	+268.3230	8.65	....
9	....	12.97	37.21	....	61.45	— 233.5100	....	3.80
10	....	11.76	48.97	5.75	86.18	+739.4244	8.58	....
	54.72	54.72				2)2792.1013	49.56	49.56
						1396.0506=Ang. spaces.		

In this example there are no indirect stations in the Northings or Southings, 54.72 is the meridianal breadth of the survey. But station 9th being indirect in the parallel breadth, must be

deducted from the sum of the Easting or Westing to find the other side of the circumscribing parallelogram. Thus:

```
       49.56 Sum E. or W.
        3.80 Indirect.
      ------
      45.76=Parallel breadth.
      54.72=Meridianal breadth.
      ------
       91.52
      32032
     18304
    22880
    ----------
    2503.9872 Content of circum. parallelogram.
    1396.0506    "    of the angular spaces.
    ----------
    1107.9366
            4
    ----------
      3.17464
           40
    ----------                 A. R. P.
      6.98560              110.3.06.98, the content.
```

In this example you may see that the four extremes are the 6th, 1st, 10th, and 4th stations. You can also see that the two latitudes of the extreme West is equal to the two latitudes of the extreme East, that is 6.17+48.55=48.97+5.75, which is a proof to so much of the work.

If you begin with the Eastings and Westings, and proceed as you were directed, all along with the Northings and Southings, you can find the content of the survey in like manner, and so prove the work.

To survey with the compass through any mine, or other cause for drawing the compass needle off its parallelism:

The diurnal variation of the needle is known to every practical surveyor, but is easily corrected by examining the time of the day when the courses of long stations were taken; as from about 8 o'clock in the morning till about 2 in the afternoon, the needle varies Westerly to from about 7′08″ to about 13′21″, as shown in the following table. The surveyor can make such allowance as will (all other errors apart) insure a complete clase.

MEAN DIURNAL VARIATION FOR EVERY MONTH IN THE YEAR.

January,	0″ 7′08″	July,	0″13′14″
February,	0 8′58″	August,	0 12′19″
March,	0 11′17″	September,	0 11′43″
April,	0 12′26″	October,	0 10′36″
May,	0 13′00″	November,	0 8′09″
June,	0 13′21″	December,	0 6′58″

Now, in surveying with the compass detatched from a Theodolite, both back and fore sights should always be taken; and to make sure that no attraction exists in the first station, take a course in a contrary direction to some object, go to that object and take a back sight; if the fore and back sight agree you may be satisfied that no attraction is at your first station; but should they not agree, you must then, from the latter station, repeat the like process till you find at which of them the attraction exists; if, at the first station, either note its quantity, which allow on the next course, as in tracing old boundaries; or pay no attention to it at the starting, but continue to take the fore and back sights throughout, and as at any station the needle will be as much attracted at the fore as the back sight, the angles can all be truly found as formerly shown, and thence the true courses for calculation by latitude and departure. Thus may the expert surveyor traverse any city, mountain, or other place containing mines or other substances which attract the needle, about which I have heard many complaints.

Now to plot the last given notes, and in like manner any other survey similarly prepared:—Having the length and breadth of the circumscribing parallelogram, let it be drawn by the same

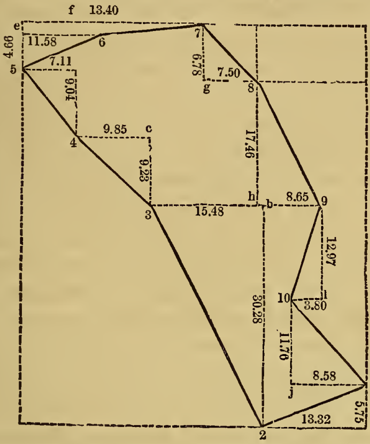


Fig. 31.

scale you intend to lay down your map by, and beginning at either of the extremes, as 1, lay off your latitude as 1.a 5.575, and at right angles to that, the departure of that station or Westing a.2 13.32, and join their extremities with the line 1 2,

which is the distance. The next station is N. W. Draw toward the North 2.b parallel to the sides of your parallelogram, and on it lay 30.28, your next Northing, and at right angles thereto toward the West 15.48, your next Westing, and join 2 and 3, which is your next distance, and so on all round, and as your Northings are equal to your Southings, and your Eastings to your Westings, your last departure, whether East or West, will fall into the point of beginning, as T.1. This is the most expeditious mode of plotting surveys, and can be made use of in the most extensive work, and is much superior to protraction by parallels and a metallic protractor. The mechanical methods of finding area, shown by many authors, I do not think well to notice, as none of them can be depended on for accuracy.

OF LOTTING OR LAYING OUT TOWNS, &C.

Regarding this kind of surveying, little can be said more than giving some general directions concerning the method of operation, as every man has mostly predetermined the manner in which he intends to have his property cut up into lots. Provide yourself with a 20 or 25 feet pole, ten

skivers with sharp points and thin edges, two brass plummets with steel points hung to fine cords; then having fixed poles so as to direct you in a straight line, and set them perpendicular by the help of your plumb, direct your assistant to hold one end of your pole in the straight course, with his plummet hanging over the extremity, whilst you hold yours touching the end of the pole which you hold, and the point of your plummet exactly over the starting point; when both plummets are steady, order your assistant to stick, and exactly where the point sticks, he sticks one of his skivers edgewise and slanting, so as that you can, when you arrive at it, hang the point of your plummet exactly over the edge of the skiver, and your assistant again sticks his plummet in the ground, and a skiver as before, and so on to the end. By measuring carefully in this manner, property can be laid out with great accuracy.

Almost every man has his own method of keeping his field-book, but the following method, which I have always adopted, is, I think, best calculated to prevent confusion in extensive surveys, for as writing backward and chaining forward are contrary, it is more congenial, and natural, to both

write and chain forward, by beginning at the bottom of the page.

N. B. It may not be unacceptable to the reader to see these notes, calculated by Noble's method, as on page 47.

Maple	60.00 35.10 N.77$\frac{3}{4}$W. (5)	Pin Oak 0.5
W. O. Stump. Tustan's Land.	41.40 162$\frac{1}{4}$ S. 17$\frac{3}{4}$W. (4)	
Sugar 0.6	36.40 33.00	To a stone.
	21.00	
	15.00 7.00 252$\frac{3}{4}$ S. 72$\frac{3}{4}$E. (3)	S. O. 0.10 toChesnut
Heirs. B. Oak O'Hara's	41.00 26.00 4.00 251$\frac{3}{4}$ S. 71$\frac{3}{4}$E. (2)	To a post. Dogwood
	20.00 269$\frac{1}{2}$ S. 89$\frac{1}{2}$E. (1)	chains to a hickory tree.

Samuel Furguson.	18.48	To the place of beginning.
	7.10 3.24 N. 5$\frac{3}{4}$ E. (7)	R. O. 0.15 to a Pine
	36.25	To a post.
Edward Kinsley.		Chesnut.
	23.00 10.00 7.00 N.30$\frac{3}{4}$W. (6)	0.10 to a Beech
	66.00 62.00	Shellbark Hickory. Stream North 36 West.

Begins at a White Oak on Squire Hays' Estate.

The foregoing method of keeping a field book, I think, is the most convenient I have seen. The following is the calculation of the notes corrected by the foregoing rules.

		F. Poles.	N.	S.	Lat. 32.05	L.A.	E. Area.	W. Area.	E.	W.
1	S. 89½	10.00		0.10	31.95	64.00	640.0000		10.00	
2	S. 71¾ E.	20.50		6.55	25.40	57.35	1115.4575		19.45	
3	S. 72¾ E.	18.40		5.50	19.90	45.30	795.9210		17.57	
4	S. 17¾ W.	20.90		19.90	0.00	19.90		126.9620		6.38
5	N. 77¾ W.	33.00	6.94		6.94	6.94		223.8150		32.25
6	N. 30¾ W.	18.25	15.68		22.62	29.56		275.7948		9.33
7	N. 5¾ E.	9.48	9.43		32.05	54.67	51.3898		0.94	
			32.05	32.05			2602.7683	626.5718	47.96	47.96

626.5718

Double area, 2.0)1976.1965 in square four pole chains.

98.809825
4

3.239300
40

9.572000

A. R. P.
98.3.0957

N.	S.	Lat. South.	Lat. North.	Lats. Added.	Double Semi-rectangles.	E.	W.
	0.10		0.10	0.10	—1.0000	10.00	
	6.55		6.65	6.75	+131.2875	19.45	
	5.50	19.90	12.15	18.80	+330.3160	17.57	Ex. E.
Ex. S.	19.90	00.00		19.90	—128.9620		6.38
6.94		6.94		6.94	+223.8150		32.25
15 68		22.62	9.43	29.56	+275.7948	Ex. W.	9.33
9.43	North.		00.00	9.43	+8.8642	0.94	
32.05	32.05				2)1098.0395	47 96	47.96

Content of the angular spaces, 549.0197

```
   47.96 Parallel breadth.
   32.05
  ------
   23980
  9592
 14388
 -------
 1537.1180 Content of circum. parallelogram.
  549.0197     "    of the angular spaces.
 ---------
  988.0983
         4
 ---------
  3.23932
       40                A. R. P.
 ---------               98.3.95.73 the same as before.
  9,57280
```

There are no indirect stations in the above, but were the longitudes made use of instead of the latitudes, the last station would be indirect; and here also it may be seen that the sum of the opposite latitudes, against the extremes East and West, are equal, viz: 12.15+19.90=32.05 and 22.62+9.43=32.05.

OF THE TRACING OF OLD MEARINGS.

Gummer, in his work on Surveying, gives the general number 57.3°, for doing this which many

work with, although it is not correct, but comes out pretty near the truth when the chain line is not very long.

To find this number, say 6.2831853 (the circumference of a circle whose diameter is 2) : 360° :: 1 : 57.3° nearly. Now if two corners are known, and can be both seen, set your compass at one of them, and direct your sights to the other; the difference between that shown by your needle, and that shown in the deed, will be the variation to be allowed on each course round the land, supposing all those given in the deed to have been correctly taken at the time the survey was made, which frequently happens not to be the case. If the two corners cannot be seen from each other, run the course and distance given in the deed, and observe if the point you arrive at, joined to the corner, form an Isoseless triangle, which will be the case if all be right; otherwise some mistake has been made in the distances, which must be corrected. Then take the pendicular distance to the given corner, and say: As the measured distance is to the distance to the corner, so are 57.3° to the number of degrees, minutes, or seconds, as the case may be, which will be the variation. Or,

more accurately. As the distance to where the perpendicular was taken is to radius, so is the distance to the corner to the tangent of the variation. In running your trial line, you will be told you are wrong, and that you don't understand your business, and all such stuff, will be sounded in your ears; but pay no attention to such nonsense, for it is to be regretted that too many men are so ignorant as to think that a Surveyor can, by some mysterious means, direct his compass on the exact line, and find all the courses as if by magic. It often happens that the corners runs through clumps of trees or other obstructions through which you cannot chain. In such a case I have often chosen an opening some degrees to right or left of the fence, and at certain distances driven posts till I found a perpendicular to the corner. Then, as the whole distance is to the perpendicular, so is each distance from the beginning to the perpendicular distance from the measured line to the fence, which, being correctly laid off, and posts driven at their extremities, will point out the true boundary.

OF LEVELLING.

The art of levelling consists in finding or tra-

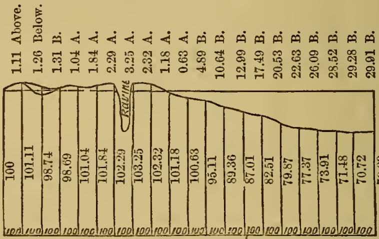
cing a line on a given portion of the earth's surface, parallel to the horizon at all points. The subject is too extensive to be comprised in this small treatise. I shall give an example, which it is hoped will enable the reader to do anything of that nature that may come in his way. Any one desirous of being fully informed on that subject, should consult Bruff's Engineering, where every information on that subject can be obtained. Regarding the adjustment of the level, which is a simple matter, let the practitioner always place his level in the middle, between the back and fore-sights, and keep the bubble in the middle of the divisions, and all will be right.

FIELD BOOK DISTANCES, MEASURED WITH A ONE HUNDRED FEET CHAIN.

Elevation.	Back sight.	Fore sight.	Depression.	Total elevat'n Datum 100 feet.	Distance.	Remarks.
				100.	0 .00	
1.11	6.84	5.73	....	101.11	100	
....	5.73	8.10	2.37	98.74	100	On cross road 50
....	8.10	8.15	0.05	98.69	100	ft. W. N. 54 W.
2.35	8.15	5.80	....	101.04	100	Side of ravine, 30
0.80	5.80	5.00	....	101.84	100	feet deep.
0.45	5.00	4.55	....	102.29	100	10. bottom 10 ft. wd.
0.96	5.01	4.05	....	103.25	100	Top of bank on
....	4.05	4.98	0.93	102.32	100	other side.
....	4.98	6.12	1.14	101.18	100	
....	6.12	6.67	.55	100.63	100	
....	2.25	7.77	5.52	95.11	100	
....	7.77	13.52	5.75	89.36	100	Middle of stream,
....	3.95	6.30	2.35	87.01	100	N. 57 W.
....	6.30	10.80	4.50	82.51	100	
....	1.60	4.24	2.64	79.87	100	
....	4.24	6.74	2.50	77.37	100	
....	6.74	10.20	3.46	73.91	100	
....	2.17	4.60	2.43	71.48	100	
....	4.60	5.36	0.76	70.72	100	
....	5.36	5.99	0.63	70.09	100	
5.67	104.76	134.67	35.58	100....	Datum at top, from which	
		104.76	5.67	70.09	the reduced level is deducted,	
					giving a third proof of the	
		29.91	29.91	29.91	accuracy of the work.	

The fall in the following section from 1 to 21 is 29.91 feet; this divided into 2100 feet, the whole distance gives 1 in 70.21, the regular grade; and to find the grade in degrees, it will be as 2100 is to radius :: 29.91 to the tangent of the angle in this case 0° 49′ nearly. Here it will be observed

that the difference between the datum line and any grade, is the height above or below the base line, running through the first station. If the ordinate be greater, the difference is above base; if less, below. Some old fashioned levellers follow a more intricate plan. Thus 101.11—98.74=2.37—1.11 =1.26 above; again, 98.74—98.69=0.05, and 1.26+0.05=131 below, and so on. But this requires too much thought, when to add and when to subtract; whereas the other method is done by one subtraction.



Scale of length, 800 feet to an inch—of height, 100 feet.

TO LAY OUT A ROAD ON A REGULAR GRADE UP A HILL.

Set your instrument at the starting point, level it, and set the vane on your levelling rod to the exact height of the centre of your glass. Ele-

vate your grading instrument to the number of degrees you intend your road to be. Send forward your rod to any place where the cross wire will cut the middle of the vane, and there drive a post, and on it mark grade, and so on to the end of the road. *And to find the cuttings and fillings, the following plan is the most convenient.* Set your instrument on the starting point, measure very exactly the height of the centre of the glass, and send your rod to the first point where cutting or filling is required. Elevate your instrument to the grade, mark where it cuts the rod, and the difference of the height of the instrument and height on the rod, will be the cutting or filling. If the height of the instrument exceeds that on the rod, the difference is cutting, and per contra.

EXAMPLE:

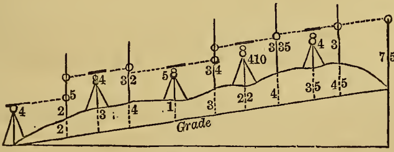


Fig. 32.

In the above cut the height of instrument is 4 feet; height of rod, 2; difference, 2 cutting.

Again, height of instrument, 4, and back sight to rod 5; difference, 1 to be added to last, gives 3 of cutting at instrument. Fore sight, 3; difference to be added to last, gives 4 feet cutting at the rod; but now, height of instrument, 5; back sight, 2; difference, 3; which, deducted from 4, leaves 1, and so through the whole.

TO INFLECT IN CURVES ON RAIL ROADS AND OTHERS.

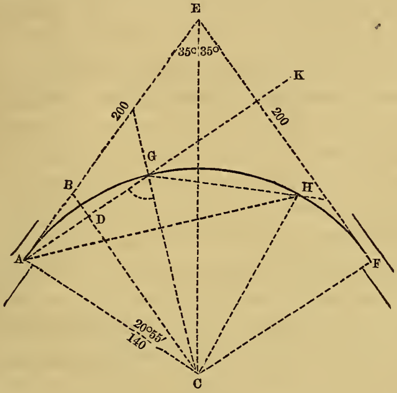
The curves most in use at the present time, are those of a circle. The angle made at the angular point of the tangents is always given—the length of your tangent is also given. To find the radius, multiply the natural tangent of half the contained angle by the length of the tangent of your curve, and the product will be the radius of the curve.

To find the degree of curvature, divide half the chord to be inflected by the radius of the curve, and it gives the natural sine of the degrees of curvature.

Thus, in the annexed figure, where the radius is 140, and the cord to be inflected 100. 140)50, 000000 (.357142 is the natural sine of 20° 55′= the degrees of curvature.

DEMONSTRATION.

The angle A D C, is a right ∠=to A D B, and A C B is common to the two triangles, A B C and A D B. Hence ∠ A C D=B A D$\frac{1}{2}$, the ∠ angle of deflection. Now set your instrument at A, direct your index to E, turn it towards the curve



till 20° 55′ are told on the limb, holding the end of your chain at A; let the assistant hold the chain tight, and move round till the other end comes in the line of the perpendicular wire of the

telescope at G, and then fix a pin. Again, if nothing intervene to prevent your seeing, inflect from A E, double the said $\angle$, and fixing one end of the chain at G, let the other be stretched to come in contact with the telescope at H, and so on through the whole. If H cannot be seen from A, move the instrument to G, and take a back sight to A, and inflect double the $\angle$ of the degrees of curvature from G K, which will fall into H.

I have met with some calling themselves engineers, who adopt the following plan. They divide 57.,3°×60=3438′ by the radius of the circle, multiplying the quotient by the number of feet in the chord, and divide by 60 for double the angle; but this is erroneous. I remember having met with a person who declared that the angle found by this rule was the true angle of deflection. I gave him the tangent 100, and the radius 100 feet, and he did it by this rule, viz: 100)3438(34.38×100= 3438+60=57° 18′. In this instance the $\angle$ made by the tangent and chord is only 45°, so that instead of inflecting in 100 feet, this 57° 18′ would fall below the chord. Nor is the half of it correct, viz: 28° 39′. For by the true method 100)50(=,5, the natural sine of 30° the true angle.

It remains to find the length of the curve A G H F. The circumference of a circle whose diameter is 2, is 6.2832 nearly. Hence as 360° : 6.2832 :: 1 : .01745, &c. This number, multiplied by the degrees in the arc, and by the radius of the curve, gives the length of the arc, thus:

$$
\begin{array}{r}
01745 \\
11 \\
\hline
17450 \\
1745 \\
\hline
1,91950 \\
140 \\
\hline
7678000 \\
191950 \\
\hline
268,73000
\end{array}
$$

$268.\frac{73}{100}$ the length of the arc, and so of any other.

The two following problems may be amusing to some readers, viz:

A gentleman has a lot 40 perches long and 30 perches wide. He thinks the ends may be so applied, as that when their extremities are joined, the area may be the greatest possible. The perpen-

dicular breadth, and the length of the unknown side are required.

Answer: Breadth, 26.815 nearly.

Length of the unknown side, 66.904 nearly.

PROBLEM SECOND.

A plank road is to be made from the city A to the town B, 20 miles asunder. A straight road is so situated that a perpendicular from A to it is 10 miles, and from B 6 miles. The plank road must touch the straight road in such a point as to be the shortest possible by that route, the length of the plank road, the point of contact, and radius of the curve having 200 feet tangent, are required.

Answer: Length of the plank road, 25.298

The distance of the point of contact from A, 12.2474

And from B, 7.3484

Radius of the curve having 200 feet tangent, 245 feet nearly.

This note to be placed after the calculation of the large triangle. It is there shown that the area of any plane triangle, the three sides of which are given, is $\frac{A\,B^2.\ \text{Sine B. Sine A}}{C\qquad 2\ \text{Sine C.}}$ Which is thus proved B△A

It has been already shown that $\frac{B\,C.\ B\,A.\ \text{Sine}\ B.}{2}$ equal area of the triangle, $\therefore \frac{B\,C.\ A\,C.\ \text{Sine}\ C.}{2} = \text{area.}$

Hence B C. B A. Sine B=B C. A C. Sine C.

Multiply each side by B A, and we have

$B\,C.\ B\,A^2.\ \text{Sine}\ B = B\,C.\ A\,C.\ B\,A.\ \text{Sine}\ C.$

Divide this equation by B C, we have

$B\,A^2.\ \text{Sine}\ B = A\,C.\ B\,A.\ \text{Sine}\ C.$

Multiply each side by Sine A $\therefore$

$B\,A^2.\ \text{Sine}\ B.\ \text{Sine}\ A = A\,C.\ B\,A.\ \text{Sine}\ A.\ \text{Sine}\ C.$

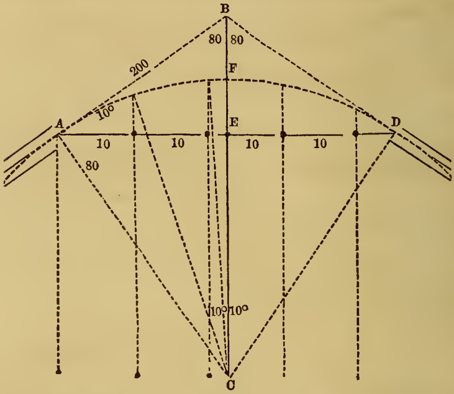
Divide this by Sine C, and

$\frac{B\,A^2.\ \text{Sine}\ B.\ \text{Sine}\ A.}{\text{Sine}\ C} = A\,C.\ B\,A.\ \text{Sine}\ A. =$ twice the area, and therefore

$$\frac{A\,B^2.\ \text{Sine}\ B.\ \text{Sine}\ A}{2\ \text{Sine}\ C} = \text{Area}$$

To find the perpendicular ordinates from the chord 6 of any arc of a railroad, in order to set off the curve correctly and speedily, without the help of an instrument, suppose it to be a 20° curve, the tangent 200. Find the radius, as formerly taught; multiply the radius by the natural co. sine of half the vertical angle, and you have ½ the chord.

Multiply the radius by the natural sine of the same angle, and you have the distance from the centre to the middle of the chord, a constant number to be deducted. Now take any distance, suppose 10 feet, at which you choose to erect your



ordinates, and from the semi-chord subtract this number, square the remainder, and subtract it from the square of the radius; extract the square root, from which take the aforesaid constant number, and the remainder is the ordinate to be rightly applied, and so proceed till you arrive at

the middle of the chord; then the difference between the said constant number and the radius, is the versed sine or greatest ordinate, and now you are prepared to lay off the other side of your curve, and all this can be done in a few minutes in the field.

EXAMPLE. See last figure.

```
Nat. tangent of 80°=5.67128
                          200
                    ---------
                   1134,25600=Radius, 1134.
Nat. co. sine of 80°   =,17365
                    ---------
                      5671280
                     6805536
                    3402768
                   7939792
                  1134256
                  ----------
                  196,96355440=Semi-chord, 197.
                  ============
Nat. sine of 80°     1134
                      ,9848
                     ------
                       9072
                      4536
                     9072
                    10206
                  --------
                  1116,7632 Distance from centre to said
                                 chord=1117.
```

From 1134
Take 1117

17 = Versed sine F E—From 197
Take 10

$(187)^2 = 34969$

From $(1134)^2 = 1285956$
Take $(187)^2 = 34969$

1250987 = 1118
From which take 1117

1 ft. the 1st ordinate.

Again, for the 2d ordinate, $197 - 20 = (177)^2$
$= 31329$ and 1285956
— 31329

$\sqrt{1254627}$ (1120   From 1120
Take 1117

3 = the next.

1

21)25
21

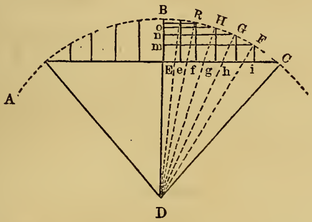
222)446
444

2240)227

Ordinate. All this is plain from the figure, and when the radius and constant subtrahend are

found (which is only the work of a minute) all the others are nearly had at sight. This I consider quite superior to any other method now in practice.

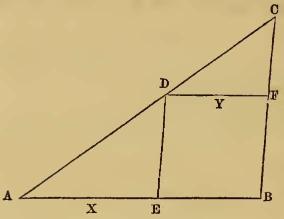
Otherwise thus: Let the radius, versed sine, chord, and constant quantity D E, be found as



before, divide the semi-chord into any number of parts as e f g h i. From E C deduct one of the parts i C, leaves E i=m F, then D F=(radius) squared—$(m\ F)^2 = (m\ D)^2$ the square root of which, minus the constant quantity, E D, gives the ordinate i F, and in like manner all the others are found, and thus the curve can be laid off in a few minutes in the most accurate manner, (by the 47th of the first of Euclid.)

PROBLEM.

Let A B C be a right angled triangle, the hypothenuse of which is 35, and the difference between the area of the enscribed square (one of whose angles coincides with the right angle of the triangle) and the area of the $\triangle$ is 150. Required the sides of the triangle.



SOLUTION.

Put A E=x and D F=y. Then per 4th Euc. 6th, y : y :: x : $\frac{y^2}{x}$=C F, $\frac{y^3}{x}$+x y=Double the area of the $\triangle$s A D E and D F C ∴=300 or $\frac{2y^3}{x}$+ 2 x y=600. Also $\frac{y^2}{x}$+ Y=B C and x+y = A B. Now $(\frac{y^2}{x}+y)^2+(x+y)^2=35^2$ viz: $\frac{y^4}{x^2}+\frac{2y^3}{x}+y^2$ $+^2y^2+2\ x\ y=1225$

Deduct $\qquad \frac{2y^3}{x} \qquad +2\ x\ y=600$

$\frac{y^4}{x^2}+2\ y^2+x^2=625$ Ex't the square.

Root and $\quad \frac{y^2}{x}+x=25$ or

$y^2+x^2=25\ x=A\ D^2=5\ \sqrt{\ }\ x.$

Hence $5\sqrt{x} : x :: 35 : x+y$, and by dividing the first and third by 5, $x^{\frac{1}{2}} : x :: y \; x+y$ and :: are their squares. $x : x^2 :: 49 . x^2+y^2+2xy$. Multiply the extremes and means, and

$$49x^2=x^3+xy^2+2x^2y \div \text{by } x \text{ and}$$

From $49x=x^2+y^2=2xy$; but $25x=y^2+x^2$.·.
Take $25x=x^2+y^2$

$24x=2xy$ or

$24=2y$ and

$y=12$ the side of the square.

And the sides of the angle are 21 and 28.

$$\begin{array}{r} 28 \\ 21 \\ \hline 28 \\ 56 \\ \hline 2)588 \\ \hline 294 \end{array} \text{=area of } \triangle.$$

Deduct, 144

150=area of the 2 △'s.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
			0¼	19¾	0½	89½	0¾	89¼
1			0.9999	0.0043	0.9999	0.0087	0.9999	0.0131
2			1.9999	0.0087	1.9999	0.0174	1.9998	0.0262
3			2.9999	0.0131	2.9998	0.0261	2.9997	0.0392
4			3.9999	0.0174	3.9998	0.0349	3.9996	0.0523
5			4.9999	0.0218	4.9998	0.0436	4.9995	0.0654
6			5.9999	0.0262	5.9997	0.0523	5.9994	0.0785
7			6.9999	0.0305	6.9997	0.0611	6.9993	0.0916
8			7.9999	0.0349	7.9997	0.0698	7.9992	0.1047
9			8.9999	0.0393	8.9996	0.0785	8.9991	0.1178
	1°	89°	1¼	88¾	1½	88½	1¾	88¼
1	0.9998	0.0174	0.9997	0.0218	0.9996	0.0262	0.9995	0.0305
2	1.9997	0.0349	1.9995	0.0436	1.9993	0.0523	1.9990	0.0610
3	2.9995	0.0523	2.9993	0.0654	2.9989	0.0785	2.9986	0.0916
4	3.9994	0.0698	3.9990	0.0872	3.9986	0.1047	3.9981	0.1221
5	4.9992	0.0872	4.9988	0.1090	4.9982	0.1309	4.9976	0.1527
6	5.9991	0.1047	5.9985	0.1309	5.9979	0.1570	5.9972	0.1832
7	6.9989	0.1221	6.9983	0.1527	6.9976	0.1832	6.9967	0.2137
8	7.9988	0.1396	7.9981	0.1745	7.9972	0.2094	7.9962	0.2443
9	8.9886	0.1570	8.9978	0.1963	8.9969	0.2356	8.9958	0.2748
	2°	88°	2¼	87¾	2½	87½	2¾	87¼
1	0.9994	0.0349	0.9992	0.0392	0.9990	0.0436	0.9988	0.0479
2	1.9987	0.0698	1.9984	0.0785	1.9981	0.0872	1.9977	0.0959
3	2.9981	0.1047	2.9977	0.1178	2.9971	0.1308	2.9965	0.1439
4	3.9975	0.1396	3.9969	0.1570	3.9962	0.1745	3.9954	0.1919
5	4.9969	0.1745	4.9961	0.1963	4.9952	0.2181	4.9942	0.2399
6	5.9963	0.2094	5.9954	0.2355	5.9943	0.2617	5.9931	0.2878
7	6.9957	0.2443	6.9946	0.2748	6.9933	0.3053	6.9919	0.3358
8	7.9951	0.2792	7.9938	0.3141	7.9924	0.3489	7.9908	0.3838
9	8.9945	0.3141	8.9930	0.3533	8.9914	0.3926	8.9896	0.4318
	3°	87°	3¼°	86¾	3½	86½	3¾	86¼
1	0.9986	0.0523	0.9984	0.0567	0.9981	0.0610	0.9978	0.0654
2	1.9973	0.1047	1.9968	0.1134	1.9963	0.1221	1.9957	0.1308
3	2.9959	0.1570	2.9952	0.1701	2.9944	0.1831	2.9936	0.1962
4	3.9945	0.2093	3.9935	0.2268	3.9925	0.2242	3.9914	0.2616
5	4.9931	0.2617	4.9919	0.2835	4.9907	0.3052	4.9893	0.3270
6	5.9918	0.3140	5.9903	0.3402	5.9888	0.3663	5.9871	0.3924
7	6.9904	0.3664	6.9888	0.3968	6.9869	0.4273	6.9850	0.4578
8	7.9890	0.4187	7.9871	0.4535	7.9851	0.4884	7.9829	0.5232
9	8.9877	0.4710	8.9855	0.5102	9.9832	0.5494	8.9807	0.5886
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	4°	86°	4¼	85¾	4½	85½	4¾	85¼
1	0.9976	0.0698	0.9972	0.0741	0.9969	0.0784	0.9965	0.0828
2	1.9951	0.1395	1.9945	0.1482	1.9938	0.1569	1.9931	0.1656
3	2.9927	0.2093	2.9917	0.2223	2.9907	0.2354	2.9897	0.2484
4	3.9902	0.2790	3.9890	0.2964	3.9977	0.3138	3.9863	0.3312
5	4.9878	0.3488	4.9862	0.3705	4.9846	0.3923	4.9828	0.4140
6	5.9854	0.4185	5.9835	0.4446	5.9815	0.4707	5.9794	0.4968
7	6.9829	0.4883	6.9807	0.5187	6.9784	0.5492	6.9759	0.5796
8	7.9805	0.5580	7.9780	0.5928	7.9753	0.6277	7.9725	0.6625
9	8.9780	0.6278	8.9752	0.6670	8.9722	0.7061	8.9691	0.7453
	5°	85°	5¼	84¾	5½	84½	5¾	84¼
1	0.9961	0.0871	0.9958	0.0915	0.9954	0.0958	0.9949	0.1002
2	1.9923	0.1743	1.9916	0.1830	1.9908	0.1917	1.9899	0.2004
3	2.9884	0.2615	2.9874	0.2745	2.9862	0.2875	2.9849	0.3006
4	3.9846	0.3486	3.9832	0.3660	3.9816	0.3834	3.9799	0.4008
5	4.9808	0.4358	4.9790	0.4575	4.9770	0.4792	4.9748	0.5009
6	5.9769	0.5229	5.9748	0.5490	5.9724	0.5751	5.9698	0.6011
7	6.9731	0.6101	6.9706	0.6405	6.9678	0.6709	6.9648	0.7013
8	7.9692	0.6972	7.9664	0.7320	7.9632	0.7668	7.9597	0.8015
9	8.9654	0.7844	8.9622	0.8235	8.9586	0.8626	8.9547	0.9017
	6°	84	6¼	83¾	6½	83½	6¾	83¼
1	0.9945	0.1045	0.9940	0.1088	0.9935	0.1132	0.9930	0.1175
2	1.9890	0.2090	1.9881	0.2177	1.9871	0.2264	1.9861	0.2351
3	2.9836	0.3136	2.9821	0.3266	2.9807	0.3396	2.9792	0.3526
4	3.9781	0 4181	3.9762	0.4355	3.9743	0.4528	3.9723	0.4701
5	4.9726	0.5226	4.9703	0.5443	4.9678	0.5660	4.9653	0.5877
6	5.9671	0.6272	5.9643	0.6532	5.9614	0.6792	5.9584	0.7052
7	6.9616	0.7317	6.9584	0.7621	6.9550	0.7924	6.9515	0.8228
8	7.9562	0.8362	7.9524	0.8709	7.9486	0.9056	7.9445	0.9403
9	8.9507	0.9408	8.9465	0.9798	8.9421	1.0188	8.9376	1.0578
	7°	83°	7¼	82¾	7½	82½	7¾	82¼
1	0.9925	0.1218	0.9920	0.1262	0.9914	0.1305	0.9908	0.1348
2	1.9851	0.2437	1.9840	0.2524	1.9829	0.2610	1.9817	0.2697
3	2.9776	0.3656	2.9760	0.3786	2.9743	0.3916	2.9726	0.4045
4	3.9702	0.4874	3.9680	0.5048	3.9657	0.5221	3.9635	0.5394
5	4.9627	0.6093	4.9600	0.6310	4.9572	0.6526	4.9543	0.6742
6	5.9553	0.7312	5.9520	0.7572	5.9487	0.7831	5.9452	0.8091
7	6.9478	0.8531	6.9440	0.8834	6.9401	0.9137	6.9361	0.9439
8	7.9404	0.9750	7.9360	1.0096	7.9315	1.0442	7.9269	1.0788
9	8.9329	1.0968	8.9280	1.1358	8.9230	1.1747	8.9178	1.2136
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	8°	82	8¼	81¾	8½	81½	8¾	81¼
1	0.9902	0.1391	0.9896	0.1435	0.9890	0.1478	0.9883	0.1521
2	1.9805	0.2783	1.9793	0.2870	1.9780	0.2956	1.9767	0.3042
3	2.9708	0.4175	2.9689	0.4305	2.9670	0.4434	2.9651	0.4564
4	3.9611	0.5567	3.9586	0.5740	3.9560	0.5912	3.9534	0.6085
5	4.9513	0.6959	4.9483	0.7175	4.9451	0.7390	4.9418	0.7606
6	5.9416	0.8350	5.9379	0.8605	5.9341	0.8868	5.9302	0.9127
7	6.9319	0.9742	6.9276	1.0045	6.9231	1.0347	6.9185	1.0649
8	7.9221	1.1134	7.9172	1.1479	7.9121	1.1825	7.9069	1.2170
9	8.9124	1.2526	8.9069	1.2914	8.9011	1.3303	8.8952	1.3691
	9°	81	9¼	80¾	9½	80½	9¾	80¼
1	0.9877	0.1564	0.9870	0.1607	0.9863	0.1650	0.9855	0.1693
2	1.9754	0.3129	1.9740	0.3215	1.9726	0.3301	1.9711	0.3387
3	2.9631	0.4693	2.9610	0.4822	2.9589	0.4951	2.9566	0.5080
4	3.9508	0.6257	3.9480	0.6430	3.9451	0.6602	3.9422	0.6774
5	4.9384	0.7822	4.9350	0.8037	4.9314	0.8252	4.9278	0.8467
6	5.9261	0.9386	5.9220	0.9644	5.9177	0.9903	5.9133	1.0161
7	6.9138	1.0950	6.9090	1.1252	6.9040	1.1553	6.8989	1.1854
8	7.9015	1.2515	7.8960	1.2859	7.8903	1.3204	7.8844	1.3548
9	8.8892	1.4079	8.8830	1.4467	8.8766	1.4854	8.8700	1.5241
	10°	80°	10¼	79¾	10½	79½	10¾	79¼
1	0.9848	0.1736	0.9840	0.1779	1.9832	0.1822	0.9824	0.1865
2	1.9696	0.3473	1.9681	0.3559	0.9665	0.3645	1.9649	0.3730
3	2.9544	0.5209	2.9521	0.5338	2.9497	0.5467	2.9473	0.5595
4	3.9392	0.6946	3.9362	0.7118	3.9330	0.7289	3.9298	0.7460
5	4.9240	0.8682	4.9202	0.8897	4.9163	0.9112	4.9123	0.9325
6	5.9088	1.0419	5.9042	1.0676	5.8995	1.0933	5.8947	1.1190
7	6.8937	1.2155	6.8883	1.2456	6.8828	1.2756	6.8772	1.3055
8	7.8785	1.3892	7.8723	1.4235	7.8660	1.4579	7.8596	1.4920
9	8.8633	1.5628	8.8564	1.6015	8.8493	1.6401	8.8421	1.6785
	11°	79	11¼	78¾	11½	78½	11¾	78¼
1	0.9816	0.1908	0.9808	0.1951	0.9799	0.1993	0.9790	0.2036
2	1.9633	0.3816	1.9616	0.3902	1.9598	0.3987	1.9581	0.4073
3	2.9449	0.5724	2.9424	0.5853	2.9398	0.5981	2.9371	0.6109
4	3.9265	0.7632	3.9231	0.7804	3.9197	0.7975	3.9162	0.8145
5	4.9081	0.9540	4.9039	0.9755	4.8996	0.9968	4.8952	1.0182
6	5.8898	1.1449	5.8847	1.1705	5.8796	1.1962	5.8743	1.2218
7	6.8714	1.3357	6.8655	1.3656	6.8595	1.3956	6.8533	1.4255
8	7.8530	1.5265	7.8463	1.5607	7.8394	1.5949	7.8324	1.6291
9	8.8346	1.7173	8.8271	1.7558	8.8193	1.7943	8.8114	1.8327
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	12°	78°	12¼	77¾	12½	77½	12¾	77¼
1	0.9781	0.2079	0.9772	0.2122	0.9763	0.2164	0.9753	0.2207
2	1.9563	0.4158	1.9544	0.4242	1.9526	0.4329	1.9507	0.4414
3	2.9344	0.6237	2.9317	0.6365	2.9289	0.6493	2.9260	0.6621
4	3.9126	0.8316	3.9089	0.8487	3.9052	0.8657	3.9014	0.8828
5	4.8907	1.0396	4.8861	1.0609	4.8815	1.0822	4.8767	1.1035
6	5.8689	1.2475	5.8634	1.2730	5.8578	1.2986	5.8520	1.3242
7	6.8470	1.4554	6.8406	1.4852	6.8341	1.5151	6.8274	1.5449
8	7.8252	1.6633	7.8178	1.6974	7.8104	1.7315	7.8027	1.7656
9	8.8033	1.8712	8.7951	1.9096	8.7867	1.9479	8.7781	1.9863
	13°	77°	13¼	76¾	13½	76½	13¾	76¼
1	0.9744	0.2249	0.9734	0.2292	0.9724	0.2334	0.9713	0.2377
2	1.9487	0.4499	1.9467	0.4584	1.9447	0.4669	1.9427	0.4754
3	2.9231	0.6749	2.9201	0.6876	2.9171	0.7003	2.9140	0.7131
4	3.8975	0.8998	3.8934	0.9168	3.8895	0.9338	3.8854	0.9507
5	4.8718	1.1248	4.8669	1.1460	4.8619	1.1672	4.8567	1.1884
6	5.8462	1.3497	5.8403	1.3752	5.8343	1.4007	5.8280	1.4261
7	6.8206	1.5746	6.8136	1.6044	6.8067	1.6341	6.7994	1.6638
8	7.7950	1.7996	7.7870	1.8336	7.7790	1.8676	7.7707	1.9015
9	8.7693	2.0246	8.7604	2.0628	8.7515	2.1010	8.7421	2.1392
	14°	76°	14¼	75¾	14½	75½	14¾	75¼
1	0.9703	0.2419	0.9692	0.2461	0.9681	0.2504	0.9670	0.2546
2	1.9406	0.4838	1.9385	0.4923	1.9363	0.5008	1.9341	0.5092
3	2.9109	0.7258	2.9077	0.7385	2.9044	0.7511	2.9011	0.7638
4	3.8812	0.9677	3.8769	0.9846	3.8727	1.0015	3.8682	1.1084
5	4.8515	1.2096	4.8461	1.2308	4.8407	1.2519	4.8352	1.2730
6	5.8218	1.4515	5.8154	1.4769	5.8089	1.5023	5.8023	1.5276
7	6.7921	1.6935	6.7846	1.7231	6.7770	1.7527	6.7693	1.7822
8	7.7624	1.9354	7.7538	1.9692	7.7452	2.0030	7.7364	2.0368
9	8.7327	2.1773	8.7231	2.2154	8.7133	2.2534	8.7034	2.2914
	15	75	15¼	74¾	15½	74½	15¾	74¼
1	0.9659	0.2588	0.9648	0.2630	0.9636	0.2672	0.9624	0.2714
2	1.9319	0.5176	1.9296	0.5261	1.9273	0.5345	1.9249	0.5429
3	2.8978	0.7765	2.8944	0.7891	2.8909	0.8017	2.8874	0.8143
4	3.8637	1.0353	3.8591	1.0521	3.8545	1.0689	3.8498	1.0858
5	4.8296	1.2941	4.8239	1.3152	4.8182	1.3362	4.8123	1.3572
6	5.7956	1.5529	5.7887	1.5782	5.7818	1.6034	5.7747	1.6286
7	6.7615	1.8117	6.7535	1.8412	6.7454	1.8707	6.7372	1.9001
8	7.7274	2.0706	7.7183	2.1042	7.7090	2.1379	7.6996	2.1715
9	8.6933	2.3294	8.6831	2.3673	8.6727	2.4051	8.6621	2.4430
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	16°	74	16¼	73¾	16½	73½	16¾	73¼
1	0.9612	0.2756	0.9600	0.2798	0.9588	0.2840	0.9575	0.2882
2	1.9225	0.5513	1.9201	0.5596	1.9176	0.5680	1.9151	0.5764
3	2.8838	0.8269	2.8801	0.8395	2.8765	0.8520	2.8727	0.8646
4	3.8450	1.1025	3.8402	1.1193	3.8353	1.1361	3.8303	1.1528
5	4.8063	1.3782	4.8002	1.3991	4.7941	1.4201	4.7878	1.4410
6	5.7676	1.6538	5.7603	1.6790	5.7529	1.7041	5.7454	1.7292
7	6.7288	1.9295	6.7203	1.9588	6.7117	1.9881	6.7030	2.0174
8	7.6901	2.2051	7.6804	2.2386	7.6705	2.2721	7.6606	2.3056
9	8.6513	2.4807	8.6404	2.5185	8.6294	2.5561	8.6181	2.5938
	17	73	17¼	72¾	17½	72½	17¾	72¼
1	0.9563	0.2924	0.9550	0.2965	0.9537	0.3007	0.9523	0.3048
2	1.9126	0.5847	1.9100	0.5931	1.9074	0.6014	1.9048	0.6097
3	2.8689	0.8771	2.8651	0.8896	2.8611	0.9021	2.8572	0.9146
4	3.8252	1.1695	3.8201	1.1862	3.8149	1.2028	3.8096	1.2195
5	4.7815	1.4619	4.7751	1.4827	4.7686	1.5035	4.7620	1.5243
6	5.7378	1.7542	5.7301	1.7792	5.7223	1.8042	5.7144	1.8292
7	6.6941	2.0466	6.6851	2.0758	6.6760	2.1049	6.6668	2.1340
8	7.6504	2.3390	7.6402	2.3723	7.6297	2.4056	7.6192	2.4389
9	8.6067	2.6313	8.5952	2.6689	8.5834	2.7063	8.5716	2.7438
	18°	72	18¼	71¾	18½	71½	18¾	71¼
1	0.9510	0.3090	0.9497	0.3131	0.9483	0.3173	0.9469	0.3214
2	1.9021	0.6180	1.8994	0.6263	1.8966	0.6346	1.8939	0.6429
3	2.8532	0.9271	2.8491	0.9395	2.8450	0.9519	2.8408	0.9643
4	3.8042	1.2361	3.7988	1.2527	3.7933	1.2692	3.7877	1.2857
5	4.7553	1.5451	4.7485	1.5658	4.7416	1.5865	4.7346	1.6072
6	5.7063	1.8541	5.6982	1.8790	5.6899	1.9038	5.6816	1.9286
7	6.6574	2.1631	6.6479	2.1921	6.6383	2.2211	6.6285	2.2501
8	7.6084	2.4721	7.5976	2.5053	7.5866	2.5384	7.5754	2.5715
9	8.5595	2.7812	8.5473	2.8185	8.5349	2.8557	8.5224	2.8929
	19°	71°	19¼	70¾	19½	70½	19¾	70¼
1	0.9455	0.3255	0.9441	0.3297	0.9426	0.3338	0.9412	0.3379
2	1.8910	0.6511	1.8882	0.6594	1.8853	0.6676	1.8823	0.6758
3	2.8366	0.9767	2.8323	0.9891	2.8279	1.0014	2.8233	1.0137
4	3.7821	1.3023	3.7764	1.3188	3.7706	1.3352	3.7647	1.3517
5	4.7276	1.6278	4.7204	1.6484	4.7132	1.6690	4.7059	1.6896
6	5.6731	1.9534	5.6645	1.9781	5.6558	2.0028	5.6471	2.0275
7	6.6186	2.2790	6.6086	2.3078	6.5985	2.3366	6.5882	2.3654
8	7.5641	2.6045	7.5527	2.6375	7.5411	2.6705	7.5294	2.7033
9	8.5097	2.9301	8.4968	2.9672	8.4838	3.0043	8.4706	3.0412
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	20	70	20¼	69¾	20½	69½	20¾	69¼
1	0.9397	0.3420	0.9382	0.3461	0.9366	0.3502	0.9351	0.3543
2	1.8794	0.6840	1.8764	0.6922	1.8733	0.7004	1.8703	0.7086
3	2.8191	1.0261	2.8146	1.0383	2.8100	1.0506	2.8054	1.0629
4	3.7588	1.3681	3.7528	1.3845	3.7467	1.4008	3.7405	1.4172
5	4.6985	1.7101	4.6910	1.7306	4.6834	1.7510	4.6757	1.7715
6	5.6381	2.0521	5.6291	2.0767	5.6200	2.1012	5.6108	2.1257
7	6.5778	2.3941	6.5673	2.4228	6.5567	2.4514	6.5459	2.4800
8	7.5175	2.7362	7.5055	2.7689	7.4934	2.8016	7.4811	2.8343
9	8.4572	3.0782	8.4437	3.1150	8.4300	3.1519	8.4162	3.1886
	21°	69°	21¼	68¾	21½	68½	21¾	68¼
1	0.9336	0.3583	0.9320	0.3624	0.9304	0.3665	0.9288	0.3705
2	1.8672	0.7167	1.8640	0.7249	1.8608	0.7330	1.8576	0.7411
3	2.8008	1.0751	2.7960	1.0873	2.7913	1.0995	2.7864	1.1117
4	3.7343	1.4335	3.7280	1.4497	3.7217	1.4660	3.7152	1.4822
5	4.6679	1.7918	4.6600	1.8122	4.6521	1.8325	4.6440	1.8528
6	5.6015	2.1502	5.5920	2.1746	5.5825	2.1990	5.5729	2.2233
7	6.5351	2.5086	6.5240	2.5371	6.5129	2.5655	6.5017	2.5939
8	7.4686	2.8669	7.4560	2.8995	7.4433	2.9320	7.4305	2.9644
9	8.4022	3.2253	8.3880	3.2619	8.3738	3.2985	8.3593	3.3350
	22°	68°	22¼	67¾	22½	67½	22¾	67¼
1	0.9272	0.3746	0.9255	0.3786	0.9239	0.3827	0.9222	0.3867
2	1.8544	0.7492	1.8511	0.7573	1.8478	0.7654	1.8444	0.7734
3	2.7816	1.1238	2.7766	1.1359	2.7716	1.1480	2.7666	1.1601
4	3.7087	1.4984	3.7022	1.5146	3.6956	1.5307	3.6888	1.5468
5	4.6359	1.8730	4.6277	1.8932	4.6194	1.9134	4.6110	1.9335
6	5.5631	2.2476	5.5532	2.2719	5.5433	2.2961	5.5332	2.3202
7	6.4903	2.6222	6.4788	2.6505	6.4671	2.6788	6.4554	2.7069
8	7.4175	2.9968	7.4043	3.0292	7.3910	3.0615	7.3776	3.0936
9	8.3447	3.3715	8.3299	3.4078	8.3149	3.4441	8.2998	3.4803
	23	67	23¼	66¾	23½	66½	23¾	66¼
1	0.9205	0.3907	0.9188	0.3947	0.9170	0.3987	0.9153	0.4027
2	1.8410	0.7815	1.8376	0.7895	1.8341	0.7975	1.8306	0.8055
3	2.7615	1.1722	2.7564	1.1842	2.7512	1.1962	2.7459	1.2082
4	3.6820	1.5629	3.6752	1.5790	3.6682	1.5950	3.6612	1.6110
5	4.6025	1.9537	4.5939	1.9737	4.5853	1.9937	4.5766	0.0137
6	5.5230	2.3444	5.5127	2.3685	5.5024	2.3925	5.4919	2.4165
7	6.4435	2.7351	6.4315	2.7632	6.4194	2.7912	6.4072	2.8192
8	7.3640	3.1258	7.3503	3.1579	7.3365	3.1900	7.2225	3.2220
9	8.2845	3.5166	8.2691	3.5527	8.2535	3.5887	8.2378	3.6247
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	24	66	24¼	65¾	24½	65½	24¾	65¼
1	0.9135	0.4067	0.9117	0.4107	0.9099	0.4147	0.9081	0.4186
2	1.8271	0.8135	1.8235	0.8214	1.8199	0.8294	1.8163	0.8373
3	2.7406	1.2202	2.7353	1.2322	2.7299	1.2441	2.7244	1.2560
4	3.6542	1.6269	3.6470	1.6429	3.6398	1.6588	3.6326	1.6746
5	4.5677	2.0337	4.5588	2.0536	4.5498	2.0735	4.5407	2.0933
6	5.4813	2.4404	5.4706	2.4643	5.4598	2.4882	5.4489	2.5122
7	6.3948	2.8472	6.3823	2.8750	6.3697	2.9029	6.3570	2.9306
8	7.3084	3.2539	7.2941	3.2857	7.2797	3.3175	7.2651	3.3493
9	8.2219	3.6606	8.2058	3.6965	8.1896	3.7322	8.1733	3.7679
	25°	65	25¼	64¾	25½	64½	25¾	64¼
1	0.9063	0.4226	0.9044	0.4265	0.9026	0.4305	0.9007	0.4344
2	1.8126	0.8452	1.8089	0.8531	1.8052	0.8610	1.8014	0.8688
3	2.7189	1.2679	2.7134	1.2797	2.7077	1.2915	2.7021	1.3032
4	3.6252	1.6905	3.6178	1.7063	3.6103	1.7220	3.6028	1.7376
5	4.5315	2.1131	4.5223	2.1328	4.5129	2.1525	4.5035	2.1720
6	5.4378	2.5357	5.4267	2.5594	5.4155	2.5831	5.4042	2.6064
7	6.3442	2.9583	6.3312	2.9860	6.3181	3.0136	6.3049	3.0408
8	7.2505	3.3809	7.2356	3.4125	7.2207	3.4441	7.2056	3.4752
9	8.1568	3.8036	8.1401	3.8391	8.1233	3.8746	8.1063	3.9096
	26°	64°	26¼	63¾	26½	63½	26¾	63¼
1	0.8988	0.4384	0.8969	0.4423	0.8949	0.4462	0.8930	0.4501
2	1.7976	0.8767	1.7937	0.8846	1.7899	0.8924	1.7859	0.9002
3	2.6964	1.3151	2.6906	1.3269	2.6848	1.3386	2.6789	1.3503
4	3.5952	1.7535	3.5875	1.7692	3.5797	1.7848	3.5719	1.8004
5	4.4940	2.1919	4.4843	2.2115	4.4746	2.2310	4.4649	2.2505
6	5.3928	2.6302	5.3812	2.6537	5.3696	2.6772	5.3579	2.7006
7	6.2916	3.0686	6.2781	3.0960	6.2645	3.1234	6.2508	3.1507
8	7.1904	3.5070	7.1750	3.5383	7.1594	3.5696	7.1438	3.6008
9	8.0891	3.9453	8.0718	3.9806	8.0544	4.0158	8.0368	4.0509
	27°	63	27¼	62¾	27½	62½	27¾	62¼
1	0.8910	0.4540	0.8890	0.4578	0.8870	0.4617	0.8850	0.4656
2	1.7820	0.9080	1.7780	0.9157	1.7740	0.9235	1.7700	0.9312
3	2.6730	1.3620	2.6670	1.3736	2.6610	1.3852	2.6550	1.3968
4	3.5640	1.8160	3.5561	1.8315	3.5480	1.8470	3.5400	1.8624
5	4.4550	2.2699	4.4451	2.2894	4.4350	2.3087	4.4250	2.3281
6	5.3460	2.7239	5.3341	2.7472	5.3221	2.7705	5.3099	2.7937
7	6.2370	3.1779	6.2231	3.2051	6.2092	3.2322	6.1949	3.2593
8	7.1280	3.6319	7.1121	3.6630	7.0961	3.6940	7.0799	3.7249
9	8.0191	4.0859	8.0011	4.1209	7.9831	4.1553	7.9649	4.1905
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	28	62	28¼	61¾	28½	61½	28¾	61¼
1	0.8829	0.4694	0.8809	0.4733	0.8788	0.4771	0.8766	0.4810
2	1.7659	0.9389	1.7618	0.9466	1.7576	0.9543	1.7534	0.9620
3	2.6488	1.4084	2.6427	1.4199	2.6364	1.4315	2.6302	1.4430
4	3.5318	1.8779	3.5236	1.8933	3.5153	1.9086	3.5069	1.9239
5	4.4147	2.3474	4.4045	3.3666	4.3941	2.3858	4.3836	2.4049
6	5.2977	2.8168	5.2854	2.8399	5.2729	2.8629	5.2604	2.8859
7	6.1806	3.2863	6.1662	3.3132	6.1517	3.3401	6.1371	3.3669
8	7.0636	3.7558	7.0471	3.7866	7.0305	3.8173	7.0138	3.8479
9	7.9465	4.2252	7.9280	4.2599	7.9093	4.2944	7.8905	4.3289
	29	61	29¼	60¾	29½	60½	29¾	60¼
1	0.8746	0.4848	0.8725	0.4886	0.8703	0.4924	0.8682	0.4962
2	1.7492	0.9696	1.7450	0.9772	1.7407	0.9848	1.7364	0.9924
3	2.6239	1.4544	2.6175	1.4659	2.6111	1.4773	2.6046	1.4886
4	3.4985	1.9392	3.4900	1.9545	3.4814	1.9697	3.4728	1.9849
5	4.3731	2.4240	4.3625	2.4431	4.3518	2.4621	4.3410	2.4811
6	5.2477	2.9089	5.2350	2.9317	5.2221	2.9545	5.2092	2.9773
7	6.1223	3.3937	6.1075	3.4203	6.0925	3.4463	6.0774	3.4735
8	6.9970	3.8785	6.9800	3.9090	6.9628	3.9394	7.9456	3.9697
9	7.8716	4.3633	7.8525	4.3976	7.8332	4.4318	7.8138	4.4659
	30	60	30¼	59¾	30½	59½	30¾	59¼
1	0.8660	0.5000	0.8638	0.5038	0.8616	0.5075	0.8594	0.5113
2	1.7320	1.0000	1.7277	1.0076	1.7232	1.0151	1.7188	1.0226
3	2.5981	1.5000	2.5915	1.5113	2.5849	1.5226	2.5782	1.5339
4	3.4641	2.2000	3.4552	2.0151	3.4465	2.0301	3.4376	2.0452
5	4.3301	2.5000	4.3192	2.5189	4.3081	2.5377	4.2970	2.5564
6	5.1961	3.3000	5.1830	3.0226	5.1698	3.0452	5.1564	3.0677
7	6.0622	3.5000	6.0468	3.5264	6.0314	3.5528	6.0158	3.5790
8	6.9282	4.0000	6.9107	4.0302	6.8930	4.0603	6.8752	4.0903
9	7.7942	4.5000	7.7745	4.5339	7.7547	4.5678	7.7346	4.6016
	31	59	31¼	58¾	31½	58½	31¾	58¼
1	0.8571	0.5150	0.8549	0.5188	0.8526	0.5225	0.8503	0.5262
2	1.7143	1.0301	1.7098	1.0375	1.7053	1.0450	1.7007	1.0524
3	2.5715	1.5451	2.5647	1.5563	2.5579	1.5675	2.5510	1.5786
4	3.4287	2.0602	3.4196	2.0751	3.4106	2.0900	3.4014	2.1048
5	4.2858	2.5752	4.2745	2.5939	4.2632	2.6125	4.2518	2.6311
6	5.1430	3.0902	5.1295	3.1126	5.1158	3.1350	5.1021	3.1573
7	6.0002	3.6053	5.9844	3.6314	5.9685	3.6575	5.9525	3.6835
8	6.8573	4.1203	6.8393	4.1502	6.8211	4.1800	6.8028	4.2097
9	7.7145	4.6353	7.6942	4.6689	7.6738	4.7025	7.6532	4.7359
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	32°	58°	32¼	57¾	32½	57½	32¾	57¼
1	0.8480	0.5299	0.8457	0.5336	0.8434	0.5373	0.8410	0.5409
2	1.6961	1.0598	1.6914	1.0672	1.6868	1.0746	1.6821	1.0819
3	2.5441	1.5897	2.5372	1.6008	2.5302	1.6119	2.5231	1.6229
4	3.3922	2.1197	3.3829	2.1344	3.3736	2.1492	3.3642	2.1639
5	4.2402	2.6496	4.2286	2.6681	4.2169	2.6865	4.2052	2.7049
6	5.0883	3.1795	5.0744	3.2017	5.0603	3.2238	5.0462	3.2458
7	5.9363	3.7094	5.9201	3.7353	5.9037	3.7611	5.8873	3.7868
8	6.7844	4.2394	6.7658	4.2689	6.7471	4.2984	6.7283	4.3278
9	7.6324	4.7693	7.6115	4.8025	7.5905	4.8357	7.5694	4.8688
	33	57	33¼	56¾	33½	56½	33¾	56¼
1	0.8386	0.5446	0.8363	0.5483	0.8339	0.5519	0.8314	0.5555
2	1.6773	1.0893	1.6726	1.0966	1.6678	1.1039	1.6629	1.1111
3	2.5160	1.6339	2.5089	1.6449	2.5017	1.6558	2.4944	1.6667
4	3.3547	2.1786	3.3451	2.1932	3.3355	2.2077	3.3259	2.2223
5	4.1934	2.7232	4.1814	2.7415	4.1694	2.7597	4.1573	2.7778
6	5.0320	3.2678	5.0177	3.2898	5.0033	3.3116	4.9888	3.3334
7	5.8707	3.8125	5.8540	3.8381	5.8372	3.8635	5.8203	3.8890
8	6.7094	4.3571	6.6903	4.3863	6.6711	4.4155	6.6518	4.4446
9	7.5480	4.9018	7.5266	4.9346	7.5059	4.9674	7.4832	5.0001
	34	56°	34¼	55¾	34½	55½	34¾	55¼
1	0.8290	0.5592	0.8266	0.5628	0.8241	0.5664	0.8216	0.5700
2	1.6581	1.1184	1.6532	1.1256	1.6482	1.1328	1.6433	1.1400
3	2.4871	1.6776	2.4798	1.6884	2.4724	1.6992	2.4649	1.7100
4	3.3162	2.2368	3.3063	2.2512	3.2965	2.2656	3.2866	2.2800
5	4.1452	2.7960	4.1329	2.8140	4.1206	2.8320	4.1082	2.8500
6	4.0742	3.3552	4.9595	3.3768	4.9447	3.3984	4.9299	3.4200
7	5.8033	3.9144	5.7861	3.9396	5.7689	3.9648	5.7515	3.9900
8	6.6323	4.4735	6.6127	4.5024	6.5930	4.5313	6.5732	4.5600
9	7.4613	5.0327	7.4393	5.0652	7.4171	5.0977	7.3948	5.1300
	35°	55	35¼	54¾	35½	54½	35¾	54¼
1	0.8191	0.5736	0.8166	0.5771	0.8141	0.5807	0.8116	0.5842
2	1.6383	1.1472	1.6333	1.1543	1.6282	1.1614	1.6231	1.1685
3	2.4575	1.7207	2.4499	1.7314	2.4423	1.7421	2.4347	1.7527
4	3.2766	2.2943	3.2666	2.3086	3.2565	2.3228	3.2463	2.3370
5	4.0958	2.8679	4.0832	2.8857	4.0706	2.9035	4.0579	2.9212
6	4.9149	3.4415	4.8998	3.4629	4.8847	3.4842	4.8694	3.5055
7	5.7341	4.0150	5.7165	4.0400	5.6988	4.0649	5.6810	4.0897
8	6.5532	4.5886	6.5331	4.6172	6.5129	4.6456	6.4926	4.6740
9	7.3724	5.1622	7.3498	5.1943	7.3270	5.2263	7.3042	5.2582
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	36	54	36¼	53¾	36½	53½	36¾	53¼
1	0.8090	0.5878	0.8064	0.5913	0.8038	0.5948	0.8012	0.5983
2	1.6181	1.1756	1.6129	1.1826	1.6077	1.1896	1.6025	1.1966
3	2.4271	1.7634	2.4193	1.7739	2.4116	1.7845	2.4038	1.7950
4	3.2361	2.3511	3.2258	2.3652	3.2154	2.3793	3.2050	2.3933
5	4.0451	2.9389	4.0322	2.9565	4.0193	2.9741	4.0063	2.9916
6	4.8541	3.5267	4.8387	3.5478	4.8231	3.5689	4.8075	3.5899
7	5.6631	4.1145	5.6451	4.1391	5.6270	4.1638	5.6088	4.1883
8	6.4721	4.7023	6.4516	4.7304	6.4308	4.7586	6.4100	4.7866
9	7.2812	5.2901	7.2580	5.3217	7.2347	5.3534	7.2111	5.3849
	37	53	37¼	52¾	37½	52½	37¾	52¼
1	0.7986	0.6018	0.7960	0.6053	0.7933	0.6087	0.7907	0.6122
2	1.5973	1.2036	1.5920	1.2106	1.5867	1.2175	1.5814	1.2244
3	2.3959	1.8054	2.3880	1.8159	2.3801	1.8263	2.3721	1.8366
4	3.1945	2.4073	3.1840	2.4212	3.1734	2.4350	3.1628	2.4489
5	3.9932	3.0091	3.9800	3.0265	3.9668	3.0438	3.9534	3.0611
6	4.7918	3.6109	4.7760	3.6318	4.7601	3.6526	4.7441	3.6733
7	5.5904	4.2127	5.5720	4.2371	5.5535	4.2613	5.5348	4.2855
8	6.3891	4.8145	6.3680	4.8424	6.3468	4.8701	6.3255	4.8977
9	7.1877	5.4163	7.1640	5.4476	7.1402	5.4788	7.1162	5.5099
	38°	52	38¼	51¾	38½	51½	38¾	51¼
1	0.7880	0.6156	0.7853	0.6191	0.7826	0.6225	0.7799	0.6259
2	1.5760	1.2313	1.5706	1.2382	1.5652	1.2450	1.5598	1.2518
3	2.3640	1.8470	2.3559	1.8573	2.3478	1.8675	2.3397	1.8778
4	3.1520	2.4626	3.1413	2.4764	3.1304	2.4900	3.1195	2.5037
5	3.9401	3.0783	3.9266	3.0955	3.9130	3.1125	3.8994	3.1296
6	4.7281	3.6940	4.7119	3.7146	4.6956	3.7351	4.6793	3.7555
7	5.5161	4.3096	5.4972	4.3337	5.4782	4.3576	5.4592	4.3815
8	6.3041	4.9253	6.2825	4.9528	6.2608	4.9801	6.2391	5.0074
9	7.0921	6.5409	7.0678	5.5718	7.0434	5.6026	7.0190	5.6333
	39°	51	39¼	50¾	39½	50½	39¾	50¼
1	0.7771	0.6293	0.7744	0.6327	0.7716	0.6361	0.7688	0.6394
2	1.5543	1.2586	1.5488	1.2654	1.5432	1.2621	1.5377	1.2789
3	2.3314	1.8880	2.3232	1.8981	2.3149	1.9082	2.3065	1.9183
4	3.1086	2.5173	3.0976	2.5308	3.0865	2.5443	3.0754	2.5578
5	3.8857	3.1466	3.8719	3.1635	3.8581	3.1804	3.8442	3.1972
6	4.6629	3.7759	4.6463	3.7962	4.6297	3.8165	4.6130	3.8366
7	5.4400	4.4052	5.4207	4.4289	5.4014	4.4525	5.3819	4.4761
8	6.2172	5.0346	6.1951	5.0616	6.1730	5.0886	6.1507	5.1155
9	6.9943	5.6639	6.9695	5.6943	6.9446	5.7247	6.9196	5.7550
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	40°	50	40¼	49¾	40½	49½	40¾	49¼
1	0.7660	0.6428	0.7632	0.6461	0.7604	0.6494	0.7575	0.6527
2	1.5321	1.2856	1.5265	1.2922	1.5208	1.2989	1.5151	1.3055
3	2.2981	1.9284	2.2897	1.9384	2.2812	1.9483	2.2727	1.9583
4	3.0642	2.5711	3.0529	2.5845	3.0416	2.5978	3.0303	2.6110
5	3.8302	3.2139	3.8162	3.2306	3.8020	3.2472	3.7878	3.2638
6	4.5963	3.8567	4.5794	3.8767	4.5624	3.8967	4.5454	3.9166
7	5.3623	4.4995	5.3425	4.5229	5.3228	4.5461	5.3029	4.5693
8	6.1284	5.1423	6.1059	5.1690	6.0832	5.1956	6.0605	5.2221
9	6.8944	5.7851	6.8691	5.8151	6.8436	5.8450	6.8181	5.8748
	41	49	41¼	48¾	41½	48½	41¾	48¼
1	0.7547	0.6560	0.7518	0.6593	0.7489	0.6626	0.7460	0.6659
2	1.5094	1.3121	1.5037	1.3187	1.4979	1.3252	1.4921	1.3318
3	2.2641	1.9682	2.2555	1.9780	2.2468	1.9879	2.2382	1.9976
4	3.0188	2.6242	3.0074	2.6374	2.9958	2.6505	2.9842	2.6635
5	3.7735	3.2803	3.7592	3.2967	3.7447	3.3131	3.7303	3.3294
6	4.5283	3.9364	4.5110	3.9560	4.4937	3.9757	4.4764	3.9953
7	5.2830	4.5924	5.2629	4.6154	5.2426	4.6383	5.2224	4.6612
8	6.0377	5.2485	6.0147	5.2747	5.9916	5.3010	5.9685	5.3270
9	6.7924	5.9045	6.7666	5.9341	6.7405	5.9636	6.7145	5.9929
	42	48	42¼	47¾	42½	47½	42¾	47¼
1	0.7431	0.6691	0.7402	0.6723	0.7373	0.6756	0.7343	0.6788
2	1.4863	1.3383	1.4804	1.3447	1.4746	1.3512	1.4686	1.3576
3	2.2294	2.0074	2.2207	2.0171	2.2118	2.0268	2.2029	2.0364
4	2.9726	2.6765	2.9609	2.6895	2.9491	2.7024	2.9373	2.7152
5	3.7157	3.3457	3.7011	3.3618	3.6864	3.3779	3.6716	3.3940
6	4.4589	4.0148	4.4413	4.0342	4.4237	4.0535	4.4059	4.0728
7	5.2020	4.6839	5.1815	4.7066	5.1610	4.7291	5.1402	4.7516
8	5.9452	5.3530	5.9218	5.3789	5.8982	5.4047	5.8746	5.4304
9	6.6883	6.0222	6.6620	6.0513	6.6355	6.0803	6.6089	6.1092
	43	47	43¼	46¾	43½	46½	43¾	46¼
1	0.7313	0.6820	0.7283	0.6852	0.7253	0.6883	0.7223	0.6915
2	1.4627	1.3640	1.4567	1.3704	1.4507	1.3767	1.4447	1.3830
3	2.1941	2.0460	2.1851	2.0555	2.1761	2.0651	2.1671	2.0745
4	2.9254	2.7280	2.9135	2.7407	2.9015	2.7534	2.8894	2.7660
5	3.6568	3.4100	3.6418	3.4259	3.6269	3.4418	3.6118	3.4576
6	4.3881	4.0920	4.3702	4.1111	4.3522	4.1301	4.3342	4.1491
7	5.1195	4.7740	5.0986	4.7963	5.0776	4.8185	5.0565	4.8406
8	5.8508	5.4560	5.8269	5.4814	5.8030	5.5068	5.7789	5.5321
9	6.5822	6.1380	6.5553	6.1666	6.5284	6.1952	6.5013	6.2236
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF LATITUDE AND DEPARTURE.

	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.
	44°	46	44¼	45¾	44½	45½	44¾	45¼
1	0.7193	0.6946	0.7163	0.6978	0.7132	0.7009	0.7102	0.7040
2	1.4387	1.3893	1.4326	1.3956	1.4265	1.4018	1.4204	1.4080
3	2.1580	2.0840	2.1489	2.0934	2.1397	2.1027	2.1305	2.1120
4	2.8774	2.7786	2.8652	2.7912	2.8530	2.8036	2.8407	2.8161
5	3.5967	3.4733	3.5815	3.4889	3.5662	3.5045	3.5509	3.5201
6	4.3160	4.1679	4.2978	4.1867	4.2795	4.2054	4.2611	4.2241
7	5.0354	4.8626	5.0141	4.8845	4.9927	4.9063	4.9713	4.9281
8	5.7547	5.5573	5.7304	5.5823	5.7060	5.6072	5.6815	5.6321
9	6.4741	6.2519	6.4467	6.2801	6.4192	6.3081	6.3917	6.3361
	45	45						
1	0.7071	0.7071						
2	1.4142	1.4142						
3	2.1213	2.1213						
4	2.8284	2.8284						
5	3.5355	3.5355						
6	4.2426	4.2426						
7	4.9497	4.9497						
8	5.6569	5.6569						
9	6.3640	6.3640						
	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.	E. W.	N. S.

TABLES OF SURVEYS.

THE USE OF THE FOREGOING TABLES IN RELATION TO SURVEYS.

THEY show, by inspection, the alteration of latitude and departure to every degree on the compass, and that for any distance not exceeding 100.000 links.

In the uppermost rank of every division are placed the several angles and their complements, to 45°, including the quarter, half, and three-quarters of degrees; and in the left-hand column are lengths of the measured lines of the field-work, and in the common areas are the difference of latitude and departure.

EXAMPLES.

Suppose the angle to be N. E. 27½ degrees, and the line in the field measured to 6 chains, and it be required to find the Northings and Eastings of that station, under 27½ degrees, and answering to 6 in left-hand column, the number in the com-

mon area, 5.3221, which shows the Northings; and under $62\frac{1}{2}$, (which is the complement to that angle) opposite the same number in the side column, I find 2.7705, which shows the Easting of that station. If the course be the same, and distance 60 chains, remove the decimal point one place to the right-hand, and the latitude and departure will be 53.221 27,705.

And if the line were 600 chains, the course remaining the same, the Northings would be 532 chains, 21 links, and the Eastings 277 chains, 05 links.

If the measured line doth not consist of an exact number of tens, as suppose its length to be 75 chains, 03 links, or 75 chains, 34 links, and the course $27\frac{1}{2}°$; then under this angle, and opposite

C. 70 are	62.091	70 chains	32.322
5 "	4.435	5 "	2.308
0.30 links	0.266	0.30 links	0.138
0.04 "	0.035	0.04 "	0.018
Northing for 75 chains, 34 links.	66.827	Easting for 75 chains, 34 links.	34.786

And so for any other.

N. B. These tables will answer to $\frac{1}{8}°$ or $7\frac{1}{2}'$, an arithmetical mean between $\frac{1}{4}°$ and $\frac{1}{2}°$, or between $\frac{1}{2}°$ and $\frac{3}{4}°$.

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